The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
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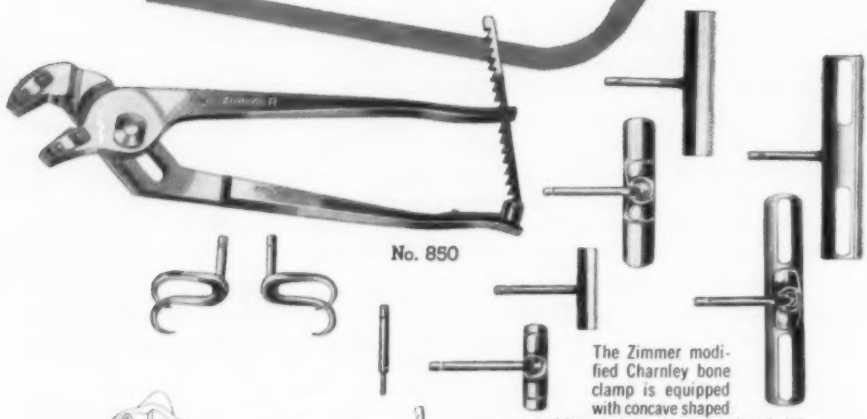

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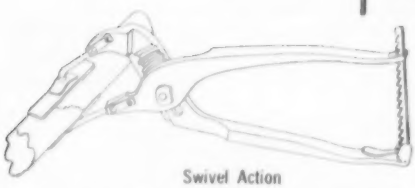

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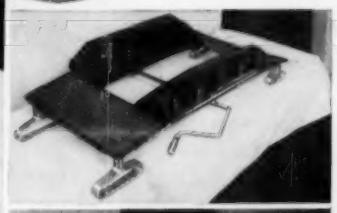

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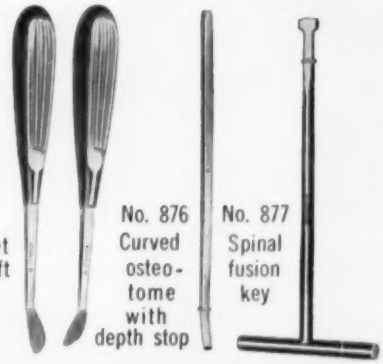

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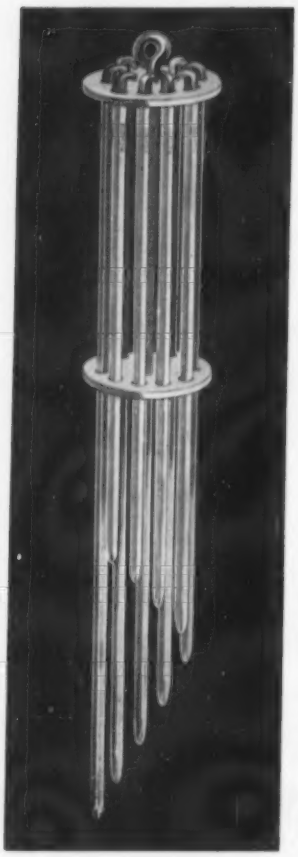

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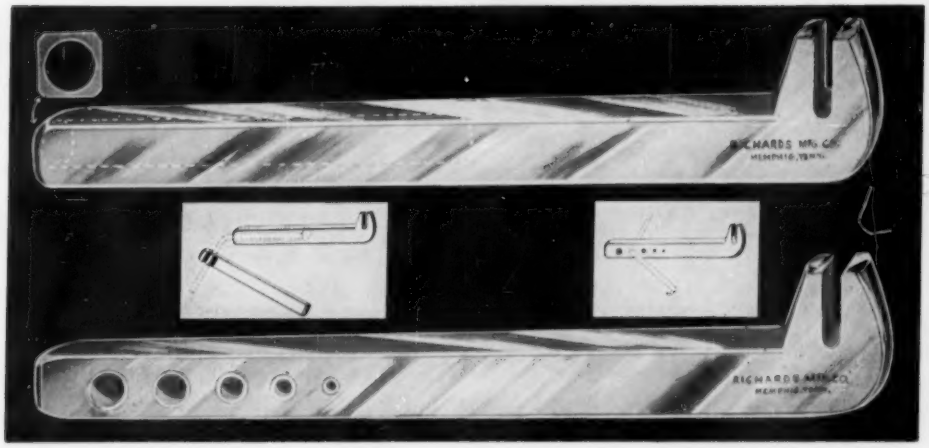

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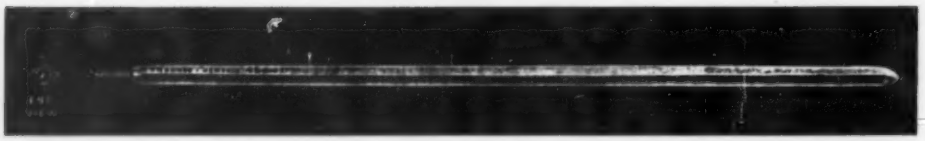

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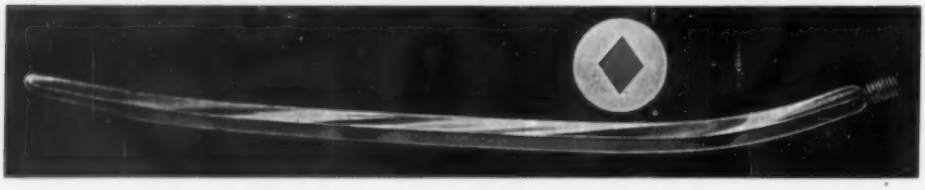

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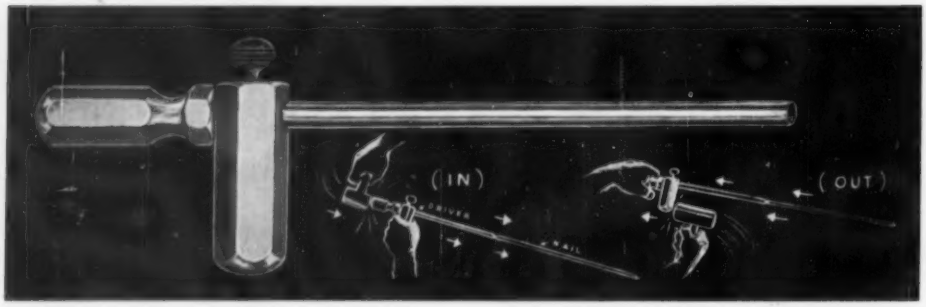

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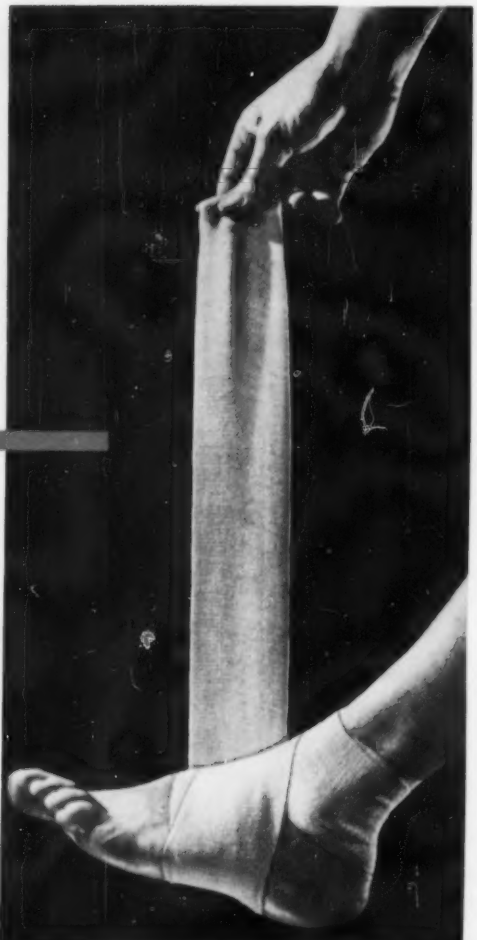

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And Tensor puts the pressure in *your* hands, Doctor. Whether you bandage for low pressure or high, you get uniform pressure over the entire bandaged area. And Tensor will maintain the pressure *you* apply.

Isn't this the kind of elastic bandage you want *your* patients to wear? Why not have your nurse order them next time she replenishes office medical supplies. Available in doctor bulk put-ups at no increase in cost.

COMPARE THESE ELASTIC BANDAGES

❶ One-foot length of bandage made with ordinary rubber is stretched after high temperature drying—and stays stretched. Its elasticity "died" in the dryer.

❷ But one-foot length of heat-resistant Tensor snaps back to its original length, even after prolonged exposure to near scorching heat of commercial dryer.

New TENSOR®
ELASTIC BANDAGE

Woven with Heat-Resistant live rubber threads

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absorbable hemostat:

Available in a large variety of sizes and forms, including:

Surgical sponges
Compressed surgical sponges
Dental packs
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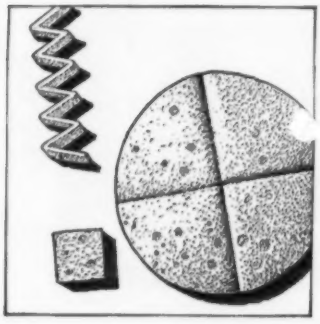
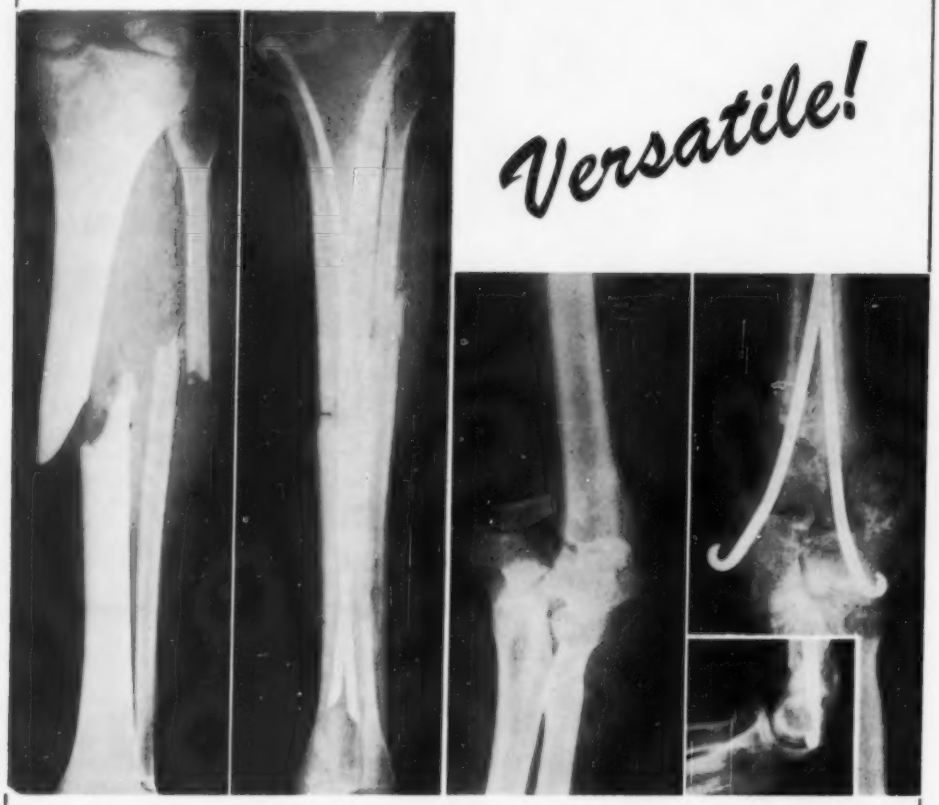
The Upjohn Company, Kalamazoo, Michigan



The RUSH MEDULLARY PIN



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Every genuine Rush Medullary Pin that has ever been made was made by *Berivon*

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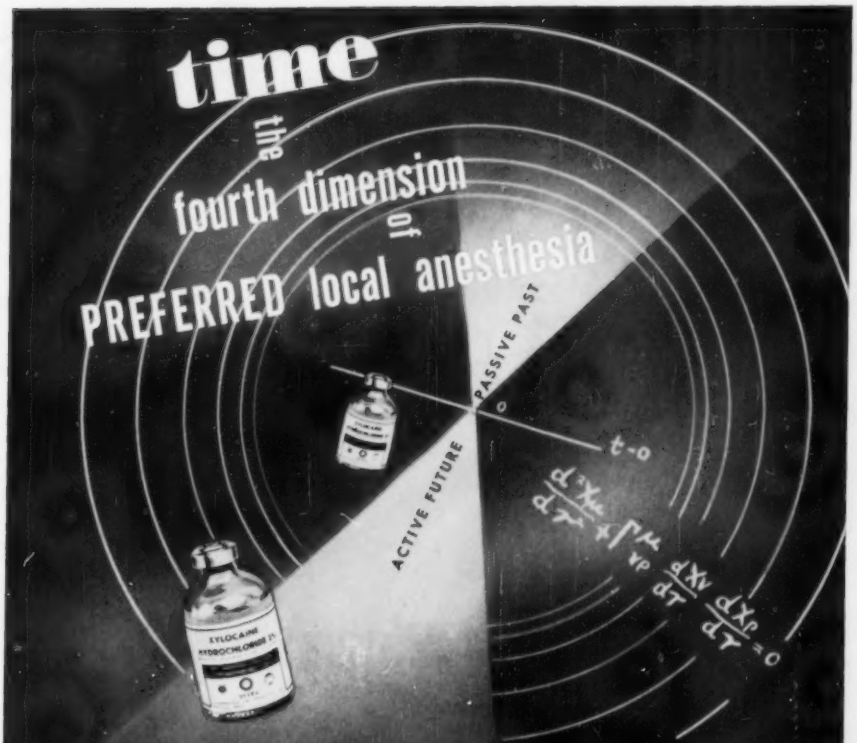
time
the fourth dimension of PREFERRED local anesthesia



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Xylocaine® Hydrochloride (Astra) merits special consideration by the busy anesthesiologist and surgeon. Profound in depth and extensive in spread, its well-tolerated effect is more significantly measured by the time saved through its remarkably fast action, by which so much normally wasted "waiting time" is converted to productive "working time".

XYLOCAINE® HCL

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(Brand of lidocaine hydrochloride*)

AN AQUEOUS SOLUTION

A 4th dimensional approach to preferred local anesthesia

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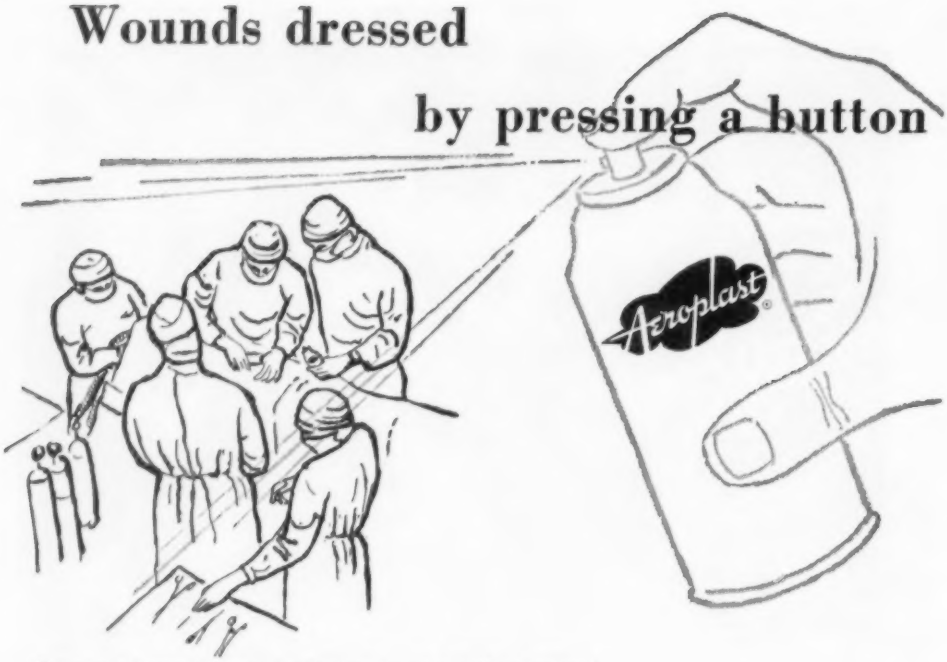
ASTRA PHARMACEUTICAL PRODUCTS, INC. WORCESTER, MASS. U.S.A.

*U.S. Patent No. 2,441,498

Wounds dressed by pressing a button



Sprayed directly onto the lesion from a self-contained aerosol "bomb", AEROPLAST replaces conventional gauze and tape dressings in all routine surgical uses.

AEROPLAST forms a transparent protective dressing over any body surface, regardless of contour, yet does not restrict circulation, respiration, or movement. Transparency, a unique advantage, permits critical evaluation of healing progress at a glance without disturbing or removing the dressing.

Aeroplast dressings are impermeable to bacteria. Aseptic lesions remain sterile as long as the dressings are allowed to remain intact. Vital fluids and electrolytes are sealed in.

Aeroplast dressings are strong and flexible; they withstand washing, friction, and the stress of motion. They are non-toxic, non-sensitizing, and non-allergenic. Easy to remove after a sufficient period for complete "setting", Aeroplast dressings are simply peeled off.

Major operative procedures such as laparotomies, thoracotomies, ileostomies, skin graft donor sites, openly reduced fractures, etc., as well as burns, excoriation, abrasions, and lacerations, are typical of the broad variety of cases in which Aeroplast has been used to advantage as the sole dressing agent.*

Supplied in 6 oz. aerosol-type dispensers through your prescription pharmacy or surgical dealer.

For reprints and literature write to: **AEROPLAST CORPORATION**
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* Choy, D. S. J.: Clinical trials of a new plastic dressing for burns and surgical wounds. A.M.A. Arch. Surg. 68:33-43 (Jan.) 1954

new: *Sklar Multiple Action* Bone Pin Cutter

CAT. No. 250-145

This new, streamlined Bone Pin Cutter adequately serves the needs of modern bone fixation—cuts all standard pins, nails or wire with unusual ease, safety and efficiency.

Shaped for easy insertion and manipulation in open wounds—chrome-plated to resist corrosion—this Sklar instrument is 15″ in length, and of long-handled construction for extra-strong leverage.

Priced at $18 each. Available through surgical supply houses.

Sklar Specialties in Stainless Steel Developed for the Orthopedic Surgeon

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Literature upon request.

CAUTION – if the name Sklar is not stamped on the instrument it is not a genuine Sklar product.

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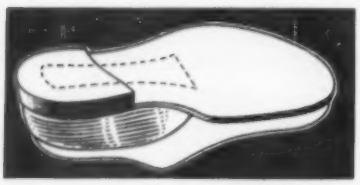

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Alden-Pedic lasts and shoes have been scientifically designed and tested to accommodate specific and general degrees of foot disabilities. Doctors who become familiar with the functional merit of this program will be glad to prescribe these shoes as a foundation in the treatment and correction of foot disabilities. We do not claim that these shoes will correct abnormal foot conditions, but they will provide the types of basic footwear necessary as a foundation in aiding foot trouble and in offering foot comfort. We know you will be glad to recommend them.

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TOWER

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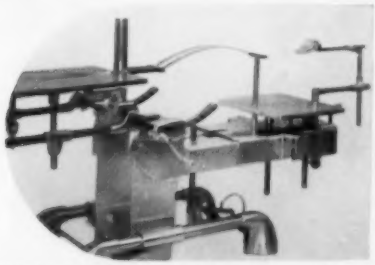

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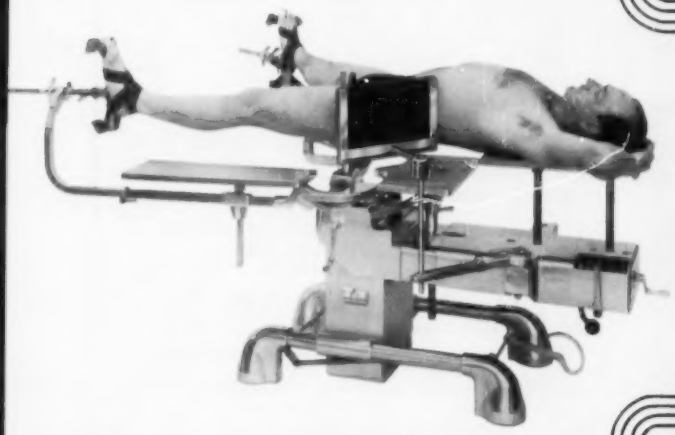

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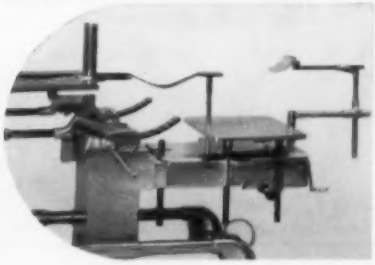

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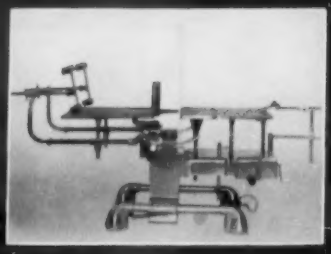

HEAD-END CONTROLS NOW AVAILABLE

Lateral cassette holder swung into place at hip. Exclusive anatomical facilities insure perfect reductions and secure immobilization during surgery, X-ray procedures, or casting to any part of the body.

Note the exclusive, time and money-saving Quic-Tach Foot Straps for quick and easy securing of the feet.

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OUR skilled technicians work hand in hand with the medical profession to keep people of all ages "on the go" — supplying orthopaedic appliances for the correction or relief of ailing or deformed feet.

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supports and appliances

head halter

The new Camp Head Halter is made of strong cream canvas lined with thick fleeced flannel for improved comfort. It is immediately available from your local authorized Camp dealer in both child and adult sizes. Comes complete with spreader bar.

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An outstanding feature of the new Camp Rib Belts is their "contour cut" which affords a snug fit and assures uniform support on the full width of the belt, forestalling any tendency to looseness along the bottom edge. Alternating pull straps provide equalized distribution of compression around the complete circumference of the belt. Special locking type buckles are easy to adjust; will not loosen while worn. Shoulder straps, crossed in back, prevent the straps from sliding off the shoulders. Made of 1/8" foam rubber vulcanized on white tackle twill, lined with thick fleeced flannel for greater patient comfort. Immediately available from your local authorized Camp dealer.

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World's Largest Manufacturers of Anatomical Supports
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DEMAND GENUINE **NEUFELD NAILS** *and* **SCREWS**

—IN **NEUTRILIUM®**

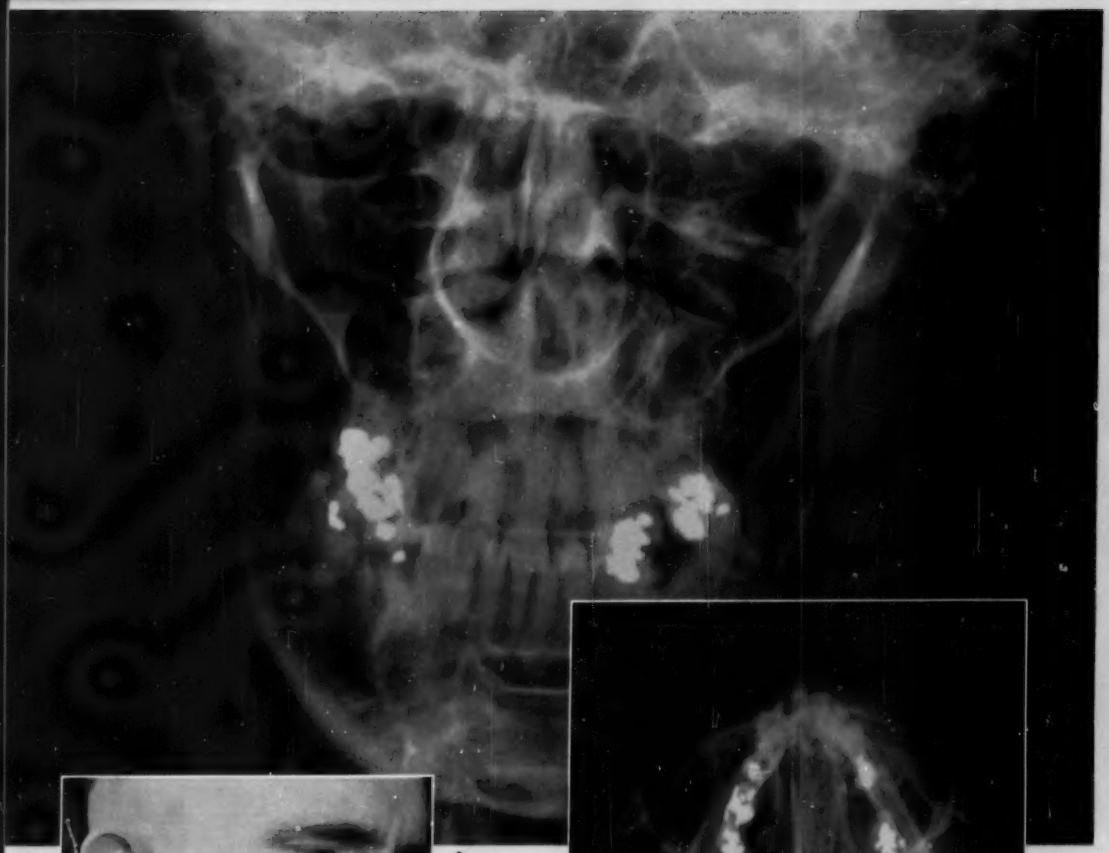
NEUTRILIUM® is the most non-corrosive metal known to science. Its proven super-strength lends an assurance of permanence to internal fixation of the trochanteric area. This neutral, non-magnetic, homogenetic alloy is entirely inert and therefore compatible with human bone or tissue, remaining unaffected by body chemistry.

NEUFELD BONE SCREWS — of ***NEUTRILIUM®*** — are cold forged and, unlike other metals, appear to be unbreakable under maximum human pressures. Heads will not twist off during application or in actual use.

GENUINE NEUFELD NAILS and SCREWS — of ***NEUTRILIUM®*** — made only by MEDICAL RESEARCH SPECIALTIES, Loma Linda, California, are sold nationally by leading surgical and orthopaedic supply dealers.

NEUTRILIUM® is a registered Trade Name of Medical Research Specialties.

NEUFELD FEMORAL NAIL PLATE
Used for internal fixation of intertrochanteric and subtrochanteric fractures.
Write for descriptive literature.
MEDICAL RESEARCH SPECIALTIES
Loma Linda, California



Photograph of patient prior to radical surgery.

▲ Preoperative posteroanterior radiograph.

Preoperative superoinferior radiograph. ▶

Partners . . . *in diagnosis, teaching, and review*

Radiography and photography work together in two important ways. They provide material for today's diagnosis and teaching and for *tomorrow's* review and research. They help physician, surgeon, and pathologist record what they see; they enable them to show what they saw—*days, weeks, years later.*

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Acrylic prosthesis.

Onlay-type guide plane to maintain articulation and to prevent drift of mandible.

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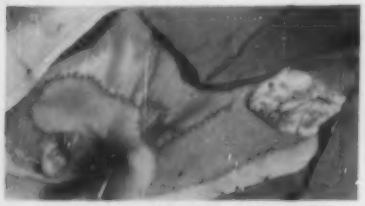
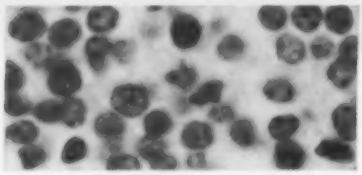
ONE-STAGE EXCISIONAL AND RECONSTRUCTIVE SURGERY.

Radical neck dissection completed.

Total parotidectomy, resection of mandible, spinofacial anastomosis, immediate mandibular reconstruction.



Closure of defect with tubed pedicle graft.



Photomicrograph (×1000) of resected tissue.

Postoperative posteroanterior radiograph.

Photograph of patient 3 weeks after operation.

Photograph of patient 22 months after operation and after detachment of tube.

For Radiographs: Kodak Blue Brand X-ray Film and Kodak x-ray processing chemicals meet the most exacting requirements. They are always dependable—uniform. Quality controlled—rigidly tested—they are *made to work together.*

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Order x-ray products from your x-ray dealer, photographic products from your photographic dealer.

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Kodak

BONY UNION IS ACCOMPLISHED EARLIER WITH THE JEWETT-TYPE, ONE-PIECE

VITALLIUM®

INTERTROCHANTERIC APPLIANCE

MICROCAST in ONE PIECE for STRENGTH and RIGIDITY... NO WELDED JOINTS... MANY APPLICATIONS... EARLIER AMBULATION... FEWER SYSTEMIC COMPLICATIONS.

*"Internal fixation with the Jewett nail, an angled appliance, has reduced hospital mortality to one-third, and development of severe senile psychosis to one-fifth of that sustained by patients treated in traction. All other complications are sharply reduced. It has produced a four-year survival rate over twice that of conservatively treated patients, while greatly improving the functional end results of the survivors."**

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Moreover, internal fixation of hip fractures promotes earlier ambulation of the patient. The Vitallium Jewett-Type appliance, designed specifically for this purpose, has proved itself. It is a strong, one-piece rigid cast appliance which has been used successfully for over 10 years in thousands of hip fractures.

Jewett-Type Vitallium appliances are ideal for many uses about the hip, and are internal fixation appliances of choice by many orthopedic surgeons. The increased use of internal fixation of this type is evidence that more and more surgeons have found the time-proven Jewett-Type Vitallium appliance a successful device not only for intertrochanteric fixation, but for femoral neck fractures and for geometric osteotomies and fusions of the hip as well.

INDICATED USES ABOUT THE HIP:

1 Sub-capital fractures
2 Trans-cervical fractures
3 Per-trochanteric fractures
4 Inter-trochanteric fractures
5 Sub-trochanteric fractures
6 Oblique or spiral fractures
7 High femoral osteotomies
8 Hip fusions

REFERENCES:

* 1. "Management of the Trochanteric Fracture of the Femur" by Mather Cleveland, M. D., David M. Bosworth, M. D., and Frederic R. Thompson, M. D. Journal of the American Medical Association, Volume 137 No. 14, July 31, 1948.

2. "The Treatment of Trochanteric Fractures" by Cecil E. Newell, M. D., American Journal of Surgery, Volume LXXIII, No. 2, February, 1947.

3. "One-Piece Angle Nail for Trochanteric Fractures" by Eugene Jewett, M. D. Journal of Bone and Joint Surgery, Volume 23 No. 4, October, 1941.

4. "The Treatment of Intertrochanteric Fractures of the Femur" by Walter G. Stuck, M.D. Surgery, Volume 15 No. 2, February, 1944.

5. "Introchanteric Fractures of the Femur" by Mather Cleveland, M. D., David M. Bosworth, M. D. and Frederic R. Thompson, M. D. The Journal of Bone and Joint Surgery, Volume 29 No. 4, October, 1947.

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LOTTES TRIFLANGE TIBIAL NAIL
Tibial Nail diameters: 5/16" and 3/8"

DRIVER AND EXTRACTOR

18-8 SMo Stainless Steel nail made in ½ inch lengths from 9 to 14½ inches.

The triflange nail is also available for femur, humerus, radius, and ulna.

The driver and extractor can be used with any of the triflange nails.

COMPOUND FRACTURE WHICH WAS DEBRIDED, CLOSED, AND PLACED IN CAST ON ADMISSION

RESULT THREE MONTHS AFTER PRIMARY HEALING OF WOUND AND CLOSED NAILING

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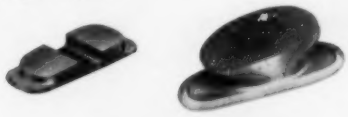
the Stryker **CAST CUTTER**

Here is the efficient and speedy cutter for cutting a window, bivalving, or removing a complete cast. Maximum convenience and safety is assured because the Stryker Cast Cutter cuts plaster by the unique principle of high-speed oscillation. No depth-gauges are required. You save precious minutes, and spare the patient needless pain and discomfort. Inquire today about these time-saving features.

WALKING HEELS

The rounded, rocker action of heel simplifies walking for the patient. Heels are light weight, easy to apply, easy to mold, and so inexpensive they may be discarded with the cast. Exclusive keystone wedge shaped design locks the Stryker heel in the plaster. Will not loosen or push through the cast. Child size heel aids the infant in balance and prevents marring of floors.



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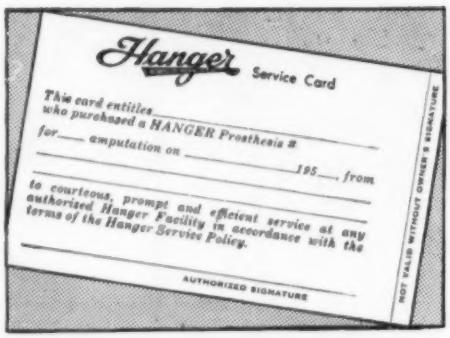
A HANGER Service Card is now being issued to every new HANGER client. This card, illustrated here, bears the individual client's name, and lists on the back all authorized HANGER service facilities, located in key cities throughout the country (see list below).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This card entitles
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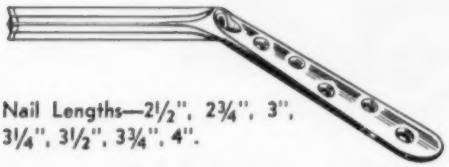
Jewett ONE-PIECE NAIL . . . AND COMPLETE SET OF INSTRUMENTS.

No. 224J—Jewett One-Piece Hip Nail. Drop forged SMO Stainless Steel—Cannulated.



Nail Lengths—2½", 2¾", 3", 3¼", 3½", 3¾", 4".

Plate Lengths—4", 5", 6".

No. 226 Guide for Jewett Hip Nail Stainless Steel

Stainless Steel Cannulated.

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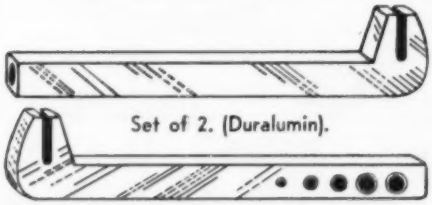

Set of 2. (Duralumin).

No. 219J Jewett Nail Plate Bending Irons.

Illustration shows one of many uses of plate bending irons.

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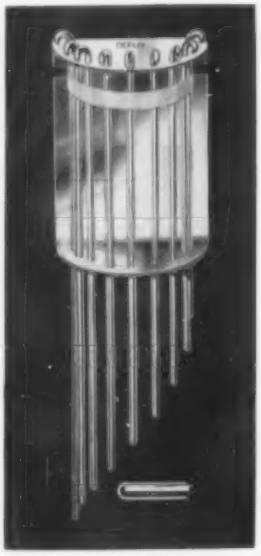

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All Stainless Steel

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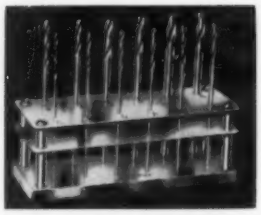

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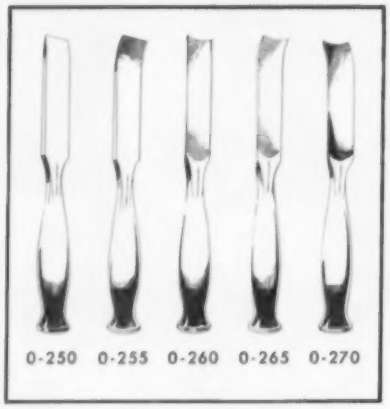

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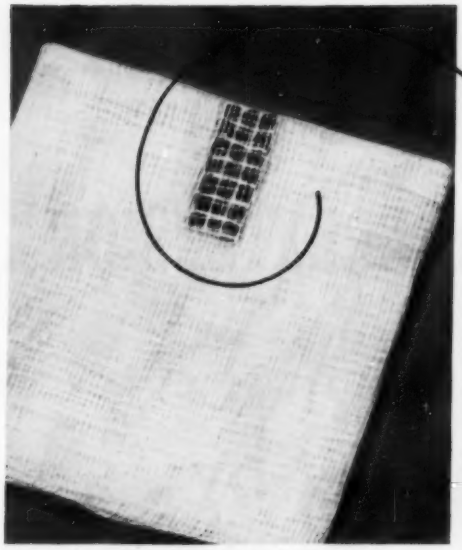

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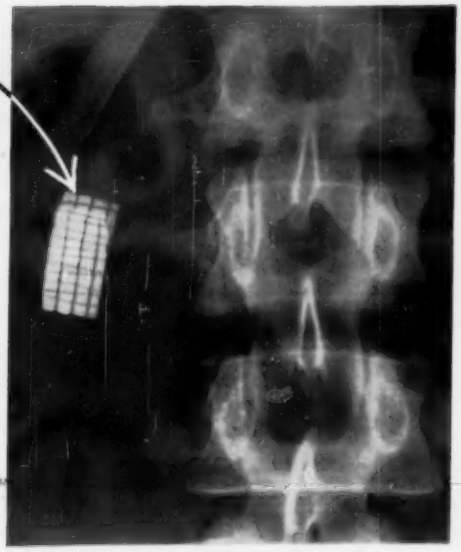

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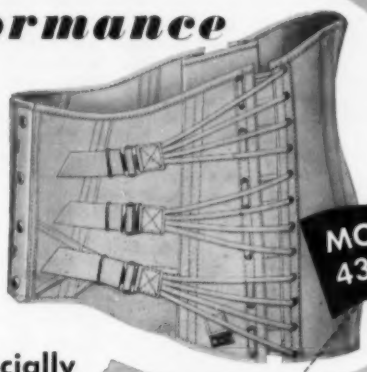

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VOL. 36-A, NO. 4 JULY 1954

The Journal of
Bone and Joint Surgery

American Volume

RESPONSIBILITY AND RESEARCH IN ORTHOPAEDIC SURGERY *

BY ALFRED RIVES SHANDS, JR., M.D., WILMINGTON, DELAWARE

For vitality, strength, and progress in medicine and its specialties, there must be a sense of responsibility, vision, and research. This concept has been many times brought to our attention in Presidential Addresses of the past, but restatement and redefinition are constantly needed. Today your President, for this "his memorable occasion", would like to define for you some of our responsibilities and to discuss a means to extend our research. First, however, he wishes to pay tribute to the wisdom, foresight, and energetic leadership of the officers of this Association who have preceded him for the part they have played in the solid growth and sound development of American orthopaedic surgery and particularly of The American Orthopaedic Association. Also, he desires to express his deep appreciation of the great honor you bestowed upon him in making him your President and to tell you what great pleasure it has given him to serve you in this high office during the past year.

RESPONSIBILITY

Nothing in the life of a medical specialty is more fundamental than the manner in which the specialty meets its responsibilities. It is the foremost quality by which a specialty is judged. This is as basic as are honesty, integrity, and a clear conscience in the character of man. A specialty must define these responsibilities frequently, face them squarely, and then take action with decision. Failure to recognize and to act on responsibilities constitutes the greatest single weakness a specialty can have.

Before beginning to outline some of our present responsibilities, we must define ourselves as orthopaedic surgeons. It has often been said that we should be physicians first, surgeons second, and specialists third. As physicians, we should be good diagnosticians, have a broad knowledge of medicine and of its specialties, and be quite familiar with all general medical practice. As surgeons, we must know surgical principles and techniques, be skilled in the use of our hands and our instruments, and at all times use good surgical sense and judgment. As specialists in orthopaedic surgery, we must clearly demonstrate knowledge and ability superior to those of other physicians in the management of the medical and surgical problems of bones, joints, and allied structures. If we do not meet these criteria of being physician, surgeon, and specialist, we cannot wholly qualify as orthopaedic surgeons. No specialty has closer affiliations with both medicine and surgery than orthopaedics; it has been stated that we must always be prepared to serve the two masters, medicine and surgery. Perhaps, as suggested by Steindler, we should rightfully be called orthopaedic physicians. When we become qualified as orthopaedic surgeons, we assume the responsibility of upholding the standards of our practice, the training of our new members, the advancement of knowledge through research, and the maintenance of amicable and understanding relationships with the medical profession and with the public.

Protection of the public and rendering good service are the first responsibilities of all

* Presented as the Presidential Address at the Annual Meeting of The American Orthopaedic Association, Bretton Woods, New Hampshire, June 9, 1954.

physicians. (The public, according to Judson, wants "experts . . . to bear the responsibility of orthopedic cases" and is ". . . the final arbiter" of our very existence as a specialty.) How this can best be done is something which each specialty must decide for itself. In medicine, too often, practitioners of a specialty go off into a little world of their own, become completely oblivious of what other branches of medicine are thinking and doing, and forget what medicine as a whole and the public expect of their specialty. To preclude the development of such a situation in orthopaedic surgery, there must be a continuing evaluation of what is good orthopaedic care, what is good judgment in the application of this care, how this care relates to other medical and surgical practices, and particularly how it relates to the patient as a whole. To see that our trainees are properly prepared to practise good orthopaedic surgery, to see that all physicians recognized as orthopaedic surgeons by the public are practising good medicine, and to see that all have a sense of loyalty to the specialty and a spirit of service to their patients and community, without too much thought of material gain—these are all important in our efforts to meet adequately the two great responsibilities, rendering of service and protection of the public.

We, as a specialty, are judged by the practices of all who do orthopaedic surgery, well trained and poorly trained, Board diplomates and non-diplomates alike. Board certification is only a beginning and does not necessarily result in better men and better practice. It is in reality only a method of evaluating by means of oral tests and written examinations the minds but not the practices of orthopaedic surgeons. Perhaps the time has come when our Board should extend its activities and establish a method of evaluating the practices of all orthopaedic surgeons. In 1919, Galloway pointed out that there were many poorly prepared surgeons calling themselves orthopaedists who were doing what they were unprepared to do, going over their depth in the surgical field, and failing to recognize their capabilities and their limitations. Although the relative number of poorly prepared orthopaedists may be less in 1954 than it was in 1919, it is still great and larger than it should be.

In the most recent Directory of the American Medical Association, published in 1950, 2,109 surgeons were listed as limiting their practice to orthopaedic surgery; up to 1950, The American Board of Orthopaedic Surgery had certified 1,534 surgeons. In the same Directory, 423 surgeons were listed as giving special attention to our specialty. Thus, the nearly 1,000 non-diplomates represented 40 per cent. of the orthopaedic practitioners in the country in 1950. It is unlikely that this percentage has changed in the last four years. Since there were 2,230 diplomates of the Board on January 1, 1954, nearly 1,500 non-diplomates must now be practising our specialty. Many of these 1,500 we know are doing excellent work, in some instances better work than that which is being done by many Board diplomates; but some are inferior, poorly trained, and are definitely not upholding accepted standards of good practice. Yet the public seldom knows the difference between this group and the well trained and well qualified group. In the minds of the people of most communities, we are labeled "bone surgeons", and the specialty is judged by the practices of all.

At the last meeting of the Academy, there were 477 registered guests. Who were these guests? Most were non-diplomates of the Board, practising orthopaedic or traumatic surgery, who had come to learn—a healthy indication of the desire on the part of some of this group for further education. To reach the orthopaedic practitioners who should be guided into the path of better work, there must be an extension of the present programs of postgraduate education. In the past twelve years, our Academy, with its papers, exhibits, movies, and instructional courses, has contributed much toward such education; but this is not enough. The program should be extended and the responsibility for this education should be not that of the Academy alone, but also that of this Association. This teaching at the postgraduate level should be taken into the different sections of the country, through regional meetings, literally into the "highways and hedges" of general ortho-

paedic practice. Some may think that this suggestion is not practical and cannot be implemented. It is being done rather effectively, however, by some of the other specialties. It is being done by the American College of Surgeons in its state and national meetings on trauma and fractures. Many of us have participated in the fracture seminars, conferences, and demonstrations of the College. The improvement in fracture care which has been evident everywhere in the last two decades, and which certainly can be partially credited to this teaching, has more than justified all effort, time, and money spent on these meetings. Similar programs for our crippled children's work, our adult work, and our rehabilitation should be instituted. Such a program should demonstrate all good orthopaedic practices, ". . . teach the principles upon which sound treatment rests to secure good results" [20], point out the common mistakes in practice, show how these can be prevented, discourage surgery of doubtful value, and thereby lead to fewer errors in practice and better care of the patient. This is a duty we owe the public. It can be accomplished if we of the Association will work together with the members of the Academy and accept this as one of our major responsibilities. It is an orthopaedic "house repair job", the putting of our house in order—a job long overdue.

Barr, in his excellent President's Address to the Academy in 1953, stressed our responsibility for protecting the public through the standardization of surgical materials. Under his leadership, a good start has been made in the establishment of the American Surgical Materials Association. Your President wishes for this new organization a long, useful, and successful life.

What shall we do, however, about the orthopaedic operative procedures which result from the development of these surgical materials? In recent years many new operations, particularly those associated with the use of metals and plastics, have not had "the test of time". It is as much our responsibility to protect the public from operations of unproved value as it is to protect it from the use of inferior materials. A young and partly trained practitioner proceeds more often with new surgical techniques, the results of which have not yet been accepted as satisfactory, than does a member of the older, more mature group. This is not wholly because of inexperience and the enthusiasm of youth; often there is an almost uncontrollable urge to be the first in a community to perform a series of new operations. Of yielding to this urge, I have been guilty; perhaps all of us have been guilty of it at some time in our careers. We must always be ready to discard the old if the new is better; but, before the old is discarded, let us be certain that there is ample and sufficient proof that the new is really better, and that the new operation qualifies, as Nix has stated, in being ". . . as simple, as satisfactory, and as safe as possible".

Gallie, in 1948, wrote, ". . . we are dealing with human lives. How much more important, therefore, that we should test our ideas thoroughly before trying them on our patients or committing them to print". It is as much our responsibility to the public to discourage the use of a surgical procedure before it has been properly tested as it is to curb unnecessary surgery. There is no doubt that every new operation, whether it be in orthopaedic surgery or in another surgical field, ". . . has left its wake bestrewn" [4] with poor results and even surgical tragedies, ". . . before clinical experience plus scientific research [has] put it into a proper perspective".[4]

Personal experiences leave indelible marks on the memory, and your President has had an extraordinary experience in dealing with young surgeons and surgical procedures. During World War II, he spent sixteen months at a desk in the Air Surgeon's Office in Washington, across which passed each month a record of the successes and failures of hundreds of all types of operations performed in over 250 Air Force Hospitals by over 1,200 general surgeons and surgical specialists, not all of whom were mature in surgical judgment and performance. The reports of complications, mistakes, and surgical tragedies were numerous, in fact, at times, appalling. Most of the worst errors reported were in the records of the young enthusiasts who were attempting to perform operations for which

they were not qualified by either training or experience. With the monthly analysis of this mass surgery at hand, the first logical step which was taken by our office to minimize these errors was a strict enforcement of the adage, "What is the best for the greatest number is the best for all". It rapidly became necessary for our office to outline to our surgeons acceptable and non-acceptable surgical procedures. In addition, regular educational conferences were held throughout the Air Force Hospitals. At these meetings emphasis was placed on the most common mistakes in judgment and therapy and on what should be done to prevent them. In the light of this record of the experience of military hospitals in wartime, which I am certain could be duplicated from civilian hospitals in peacetime if surgical reports were available, it is our responsibility to discourage and to minimize the widespread performance of new operations before reasonable proof of their safety and worth has been made available.

In orthopaedics, there are probably more different operations for the same purpose than in any other field of surgery. Boyd has said, "We have developed more operations than any other specialty. There seems to be no limit to the number of surgical procedures concerned with . . ." muscles, bones, and joints. We, more than those in any other field of surgery, need to list, to catalogue, and to recognize surgical procedures in terms of percentages of successful results or in categories of *usually successful, reasonably successful,* and *of doubtful success.* If such a classification is made by a "Board of Respected Elders", if it is generally accepted as a fair appraisal of our surgery by the members of our specialty, and if careful consideration to this classification is given by all of us before surgery is performed, it could be a source of great good. The establishment of such criteria for orthopaedic operations would not only decrease the number of bad results, but would also inform the medical profession and the public that we in orthopaedic surgery were taking a most constructive step to meet more adequately one of our great responsibilities, the protection of the public.

Reginald Sayre, fifty years ago, stated, "Until the surgeon knows how to adapt mechanical principles to the cure of deformities, he is not competent to be an orthopedist. . . ." Eleven years later, Packard stated, "Advances in surgery must go hand in hand with a rational thorough method of treatment by mechanical means", and if we ". . . simply develop the operative side of orthopedics, which can be executed with equal skill and technic by the general surgeon, our future existence will be problematical". We should ask ourselves frequently whether we are teaching our students and residents what are the sound mechanical treatments in the cure of deformities. We should further ask ourselves seriously whether we are not giving too much attention in our training and teaching to the surgical procedures of our specialty and thereby risking a problematical existence in the future. If our interest in surgery continues to become, as Painter has said, ". . . infected with the virus of operative furor" to the neglect of teaching the fundamentals of diagnosis, the principles of therapy, and the value of conservative non-operative procedures, is there not a great possibility that orthopaedic surgery may be forced to repeat its history of 100 years ago? Bradford stated that at this time, because the ". . . ambition of all men of energy prompted them to emulate those monarchs of the operating-table", the specialty went into a decline from which it took years to recover. We must ever bear in mind the saying of Santayana, "Those who cannot remember the past are condemned to repeat it". Wiles, in 1952, wrote, ". . . however important surgery may be now, it should be the aim of all doctors, including surgeons, to limit and ultimately abolish it". This opinion, coming from one of our distinguished English colleagues, should awaken our thinking. Perhaps we shall never arrive at the point of abolishing surgery, but certainly we can deemphasize it in our training and lay greater stress on teaching the principles and fundamentals of our specialty to great advantage.

The failure of orthopaedic surgeons to recognize their responsibility in the development of rehabilitation services has become one of our most serious shortcomings in recent

years. In the Armed Forces during World War II, a rather general interest among all medical officers was manifested in the rehabilitation of the sick and wounded; and among a few of these physicians, there developed a very keen interest in all aspects of rehabilitation. In this latter group, there were many who carried their interest over into practice in civilian life. These physicians later joined the medical practitioners of physical therapy and formed the specialty physical medicine, to which was added later the name rehabilitation. Since the War, unfortunately most of the orthopaedic surgeons, with a few outstanding exceptions, have continued to believe that the pre-war pattern of medical and surgical after-care is adequate. However, the lay public has been shown the tangible benefits to patients and budgets of good rehabilitation programs—of what might be called the post-war concept. This has been followed by hospital boards and community-planning agencies insisting upon rehabilitation services being instituted. The orthopaedic surgeons generally, instead of taking the lead in the organization of these services in which the public has become interested, have assumed a most apathetic attitude. This has made it possible for the specialists in physical medicine to gradually acquire the leadership in this rapidly growing medical activity in which they are interested. In reality, we have only ourselves to blame if we do not approve of the present situation, in which, in many communities and institutions, specialists in physical medicine are directing programs of rehabilitation involving the after-care of orthopaedic patients. Our British orthopaedic colleagues since the War have taken a very active lead in the development of rehabilitation services, and in their country they are now directing most of this important branch of medicine. It is unfortunate that we have not followed their lead. How futile would be all of our treatment, particularly our surgery, without proper after-care, and how dependent we are on effective rehabilitation for our patients! Wiles has rightly said that reconstructive surgery should never be attempted unless good facilities are available for rehabilitation and that these should be under the full control of the surgeons. The time is past due when every orthopaedic surgeon in the United States should consider rehabilitation to be one of his first responsibilities and should actively promote and participate in the rehabilitation services of his community.

Along with responsibility for the training of orthopaedic practitioners goes the responsibility for the training of orthopaedic teachers. For our specialty to go forward, we must have good teachers, the best we can produce. It has been said by many that we should train two types of orthopaedic surgeons, one for general practice in orthopaedic surgery and the other for full-time professorial positions, the latter to follow the paths of research and teaching. However, it should always be remembered that the good teacher and investigator should first have been a good clinician and practitioner, for, without this background, his vision may become warped and his patients may become second in importance to the laboratory experiment. If reasonable assurance of satisfactory teaching positions with adequate remuneration for those who show ability and aptitude could be given, there would be many young and promising trainees ready and willing to take this special training and to achieve higher learning in our specialty. It is my feeling that appropriate recognition in the form of special certification by our Board should be given to such training, which of necessity would be longer than the present three-year period. It is so important for orthopaedic surgery to have good teachers that serious consideration should be given to the subsidization by our specialty of selected teaching positions. At times, we become greatly concerned about the scarcity of strong, inquisitive, forward-looking minds, sufficiently talented to become our teachers and leaders. In 1926, Hoke wrote, "I do not bother about the oncoming of talented minds, for Nature has a way of producing young men from decade to decade who have the will to work, a determination to search, and a vision of usefulness, which need only be appropriated and directed somewhat". We must be ever ready to recognize the man with a talented mind and to follow the concept of Michael Hoke of appropriating, interesting, and directing this type of individual into a teaching career and a position of leadership in our specialty.

Sound, logical, realistic policies should be adopted for orthopaedic surgery and its future development. These policies should be changed seldom and only after most careful thought and deliberation. A Policy Committee for orthopaedic surgery should be established; it should steer and guide our policies through the calm or the turbulent seas of changing economic and sociological conditions, not thinking always of what is happening today, but cognizant always of what may follow on the morrow. This Policy Committee should consist of our older and wiser heads and should become the strongest active force in American orthopaedic surgery. On this Committee should be representatives, perhaps many past presidents, of the Association and the Academy, and representatives of the Orthopaedic Section of the American Medical Association. Whenever matters of policy arise in the affairs of our specialty, matters which directly affect us all, they should be referred to this Committee for its deliberate and thoughtful consideration and recommendations before being acted upon by the referring group. In this Committee should originate policies for the improvement of our specialty. Such policies should then be referred to the Association, the Academy, and the Orthopaedic Section of the American Medical Association for discussion, adoption, and action. This Joint Committee would be the logical successor to the Caldwell Committee on the Advancement of Orthopaedic Surgery of the Academy. However, in no event should the decisions of this Committee be binding on orthopaedic surgery or be considered more than recommendations to the whole membership of the organizations. To survive in the way we should, we must follow, at all times, good democratic principles and allow no small dictatorial body to arise in our midst, for, as Clemenceau once stated, "War is too important to be left only to the generals"; the members of this Committee might be likened to our generals. The establishment of a Policy Committee would evidence far sighted vision for the future. It would be one of the most effective steps we could take to ensure the continuing vitality, strength, and progress in our field of medicine which are so earnestly desired by all of us.

In 1922, Allison said that our specialty had come out of its infancy, youth, and early manhood, and had gone into a vigorous maturity. Having been fully matured for over three decades, we should, theoretically, now be in our prime. We represent today one of the largest and strongest of the medical specialties. Orthopaedic surgery has attained this position not alone because it is closely affiliated with medicine and all of surgery, but also because through wise leadership and hard work on the part of its membership over the years, it has rendered good service to the public. Each of us should now ask himself these questions: Will orthopaedic surgery stay in its prime? Will it gain greater strength? Or is our specialty going to show age, senility, and regression? If we choose to be self-satisfied and complacent, deterioration will inevitably set in. We must be ever ready to change ourselves and our concepts in light of changing conditions. One of the greatest mistakes we can make is to believe that, because we are large and strong today, our progress will be automatic. Our well-being and advancement will depend entirely upon what we do, how we do it, and the direction of our vision. Particularly will it depend upon what we do to strengthen the foundations of our specialty. This strengthening cannot take place without our devoting ourselves to the following which are essential for the development of any field of medicine—namely, (1) the meeting of responsibilities, both old and new, as they arise, (2) good clinical and basic science training programs for the development of practitioners and teachers, some of whom will become our leaders, and (3) sound basic research to provide good building material for future advances in therapy. Your President now wishes to discuss with you the third of these essentials, research, and the role it should play in the strengthening of orthopaedic surgery.

RESEARCH

Research has been mentioned prominently in ten of our Presidential Addresses and in eight of the Presidential Addresses of the Academy. Its first mention was in 1889 when

Bradford stated, "Investigation is especially needed". Eight years later, Ketch wrote, "The desire for brilliant achievement in both mechanical and surgical procedures can well give way to study and research in the undiscovered sources of deformity, congenital and acquired, and also toward a solution of the many vexed questions regarding joint and spinal diseases". In 1920, Starr stated that research is needed to "help to establish our Association on a more scientific foundation". In 1924, Baer brought the great importance of research into clearer focus than has any other president before or since. In his address, were such statements as research work is ". . . a duty one owes to his specialty and to the advancement of science". A ". . . *sine qua non* of a good teacher . . ." is his ". . . power to stimulate the spirit of investigation. . . . You are made immortal by the impression you can deliver to your students . . . [and] by the research work you do. . . . One should arrange his own time, and in organizing his staff provide sufficient time for them, that all may in some measure seek the Goddess of Truth by individual research."

In the last four Academy Presidential Addresses, Caldwell, Barr, McKeever, and Boyd have repeatedly emphasized the need for research. Caldwell wrote, "Research offers the best possibility for enlarging our field of endeavor. . . . So important is research to the future of orthopaedic surgery that we believe our Committee on Scientific Investigation should double its efforts to stimulate other centers to begin research work and to assist in obtaining the necessary funds and investigators to make this possible."

McKeever stated, "Orthopaedic surgery today is lacking in basic research . . ." and the orthopaedic surgeon ". . . has not himself . . . contributed enough of the blood, sweat, and tears which go into the advancement of general surgical knowledge as it applies both to the broad field of surgery and to his own specialty."

Barr spoke of the research needed in the study of surgical materials.

Boyd stated, "In the future, first, we should sponsor research which will develop new methods and new fields of activity for orthopaedists. Our deficiency in basic orthopaedic investigation should be corrected promptly."

Your President can do no more than to strongly endorse these opinions and state that he believes with Harris that our very future existence depends on our own creative spirits and what we ourselves do to carry on programs of fundamental research, or as Harris has so well expressed it, ". . . research into the nature and structure of bone, cartilage, muscles, and connective tissue". Research, as we all know, is dependent first on brains and second on money. Brains cannot be bought but must be found. Money is needed to support these research-talented brains after they have been found, and to provide the facilities necessary for their work. We can all do something to help provide this money. This is what your President wishes now to discuss with you.

During the past year, your Research Committee * has conducted a survey of the orthopaedic research which is being done by orthopaedic surgeons. Information has been obtained not only on what the present projects and their costs are, but also on what projects would be pursued if additional funds were available and what the probable costs of such new projects might be. It was believed by your President that these data should be obtained in order to present to you not a probable, but an actual need, and that information by name, project, and cost should be available before suggesting a means of finding the money to extend our research programs.

Through the Central Office of the Academy, questionnaires were sent to 2,250 orthopaedic surgeons, all of whom were members of the Association, or the Academy, or were diplomates of the Board. Of the 376 who replied, 189 orthopaedic surgeons in 150 institutions reported that they were carrying on 290 research projects. It is realized that this survey is incomplete, but it is believed that 80 per cent. of the orthopaedic surgeons engaged in some type of research have reported. The projects were clinical studies in forty-eight of the 150 institutions (32 per cent.), laboratory studies in thirty-five (23.4 per

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cent.), and clinical and laboratory studies in sixty-seven (44.6 per cent.). The approximate cost of the projects in 100 institutions was $490,300. On this basis, the estimated cost of all current projects in the 150 institutions was $736,800. On seventy-two questionnaires were described 146 projects which were being deferred because of the lack of funds; their cost would be $346,450. On this basis, the total estimated cost of all such deferred projects would be approximately $600,000. It is interesting to note that the National Research Council reported, as of September 1, 1953, that there were on record in the Bio-Sciences Information Exchange 336 projects dealing with research on the connective tissues and the musculoskeletal system, that is, basic orthopaedic research. Financial support being given to these projects was approximately $5,500,000. In these projects there were included twenty-two investigations by orthopaedic surgeons in thirteen institutions (6.5 per cent.)—a very small part of the total.

On many questionnaires, it was stated that the obtaining of money did not present the problem that the difficulty of finding time, personnel, and facilities presented. As we all know, funds are available from many sources for good, basic research, but they are definitely not available from many of the same sources for the orthopaedic surgeon who is untrained in research techniques, unless the circumstances of his request are unusual. Many of you will recall experiences of your own in applying to some of the foundations for research grants.

If we as a specialty are to further more extensive programs of research among ourselves and especially among our trainees and younger members with inquisitive minds and original thoughts, we must have research funds of our own, under our own control. Such funds must be raised by us. How can this be done? The answer is to establish a nonprofit, tax-exempt Orthopaedic Research Foundation to which we, our patients, and others may give and which may receive bequests from wills and other sources. It should be operated and controlled by American orthopaedic surgery with a Board of Trustees representing the Association, the Academy, and the newly organized Orthopaedic Research Society. The National Research Council, through its orthopaedic or other appropriate committee, should be asked to assist in decisions concerning what constitutes research worthy of support by the funds of such a Foundation. The urologic surgeons have led the way among the specialties in this and have operated very successfully since 1952 an American Urological Research Foundation. We should do the same, for there is nothing more important to the progress of our specialty, and nothing more vital to ourselves, than sound investigation. With careful planning and judicious management, such a foundation could prove a tremendous incentive to the growth of American orthopaedic surgery. It would be one of the most effective steps which we could take to inform medicine and all of science that we in orthopaedic surgery are now prepared to go farther than we ever have in the past to help ourselves through research. Your President hopes that such a Foundation may become a reality within the coming year.

CONCLUSION

Orthopaedic surgery of today has been left a great heritage by our forebears. It is our duty not only to preserve and to cherish but to enhance this proud inheritance. On the south portico of the Archives Building in Washington, there is a statue of a beautiful woman holding an infant against a background of stalks of ripened grain, under which appears the inscription, "The heritage of the past is the seed that brings forth the harvest of the future". The great orthopaedic surgeons of the nineteenth century and of the early part of the twentieth century were our forefathers who not only created this heritage but also planted this seed. The seed which was sown has borne fruit and has created "the harvest of the future", the orthopaedic surgery of 1954. We of this generation should be doing as our forefathers did for us; we should be "sowing the seed" to bring forth "the harvest of the future" for the oncoming generations. This should be done, as Willard

has expressed it, ". . . in such a way that we may pass on to our successors a still more perfect inheritance of which both we and they may be very proud". This is perhaps our first and greatest responsibility. How we meet this responsibility will be determined by our vision. We must always remember the proverb, "Where there is no vision, the people perish". Upon our vision rests the future of orthopaedic surgery. We can only hope that our Creator may grant to all of us and to our line the strength, wisdom, and courage to carry steadfastly the torch of our proud heritage, and at all times to maintain a clear, bright, and unobstructed vision for the future.

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ADAMANTINOMA (SO-CALLED) OF THE LONG BONES

Review of the Literature and a Report of Three New Cases*

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The stimulus to undertake this paper occurred when a man thirty-five years old came to us in April 1951 with a known diagnosis of so-called adamantinoma of the left fibula. The involved portion of the fibula had been resected nine months previously. The family physician had referred the patient because of recent roentgenographic evidence of changes in the distal third of the left tibia. An analysis of the literature at that time left unanswered certain questions which were raised concerning the care of this patient. We found that, although adamantinoma affecting the extremities was known to recur, there was no record in the literature that such a tumor had metastasized or had caused death. How then, if biopsy of this patient's left tibia disclosed a tumor, would we know whether local excision or amputation was to be the procedure of choice?

The purpose of this work was, then, to find out whether so-called adamantinoma of the long bones metastasizes, that is, whether it is malignant, and what is the treatment of choice.

MATERIAL AND METHOD

This study was based on twenty-seven cases of so-called adamantinoma (Table I and Tables II-A, II-B, and II-C). Twenty-four of these cases, including two from the Mayo Clinic, were encountered in a survey of the literature, while the other three were new cases from the Mayo Clinic which are reported herein (Cases 25**, 26, and 27).

In each case in which an operation had been performed at the Clinic (Cases 17 †, 18, 25, 26, and 27) the specimen was preserved in a solution of 10 per cent. formalin. Sections were cut from this preserved tissue. Specimens from bone were initially decalcified, em-

TABLE I

Adamantinoma (So-Called) of Long Bones: General Data

Case	Year	Author	Age, Sex	Site	Antecedent Trauma	Latent Period	Symptoms and Duration
1	1913	Fischer	37 M	Left tibia, juncture lower and middle thirds	Contusion	5 months	Pain, swelling, 5 months
2	1928	Pérochon and Veluet	50 M	Tibia, middle third			Swelling, 20 years
3	1930	Richter	12 M	Left tibia, middle third	Fall		Swelling, 8 months
4	1931	Baker and Hawksley	46 M	Left tibia, lower third	Contusion	8.5 months	Pain, swelling, 6 weeks

* Abridgment of thesis submitted by Dr. Baker to the Faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science in Orthopaedic Surgery.

** Tissue supplied by Dr. J. H. Fisher, London, Ontario, Canada.

† Tissue showing metastasis to lymph nodes supplied by Dr. Wallace Grayston, Huntington, Indiana.

TABLE I (*Continued*)

Case	Year	Author	Age, Sex	Site	Antecedent Trauma	Latent Period	Symptoms and Duration
5	1932	Ryrie	52 M	Tibia, middle third	Contusion	8 years	Swelling, 8 years
6	1933	Petrov and Glasunow	22 M	Left tibia, middle third	None	None	Swelling, 3 years
7	1934	Holden and Gray	36 F	Left tibia, lower third	Abrasion, contusion of ankle	None	Pain, 2 years
8	1937	Bishop	22 M	Right tibia, upper third	Fracture	8 weeks	Swelling, 3 years
9	1938	Rehbock and Barber	24 F	Left tibia, lower third	Sprain of ankle	None	Pain, swelling, 18 months
10	1938	Oberling, Vermes, and Chevereau	51 M	Tibia, middle third			
11	1938	Dunne	32 M	Left tibia, juncture upper and middle thirds	Contusion, abrasion	9 months	Swelling, 4 years; pain, later months
12	1938	Wolfort and Sloane	57 F	Left tibia, juncture middle and lower thirds	Contusion	None	Swelling, 19 months; pain, 4 months
13	1938	Wolfort and Sloane	18 F	Right tibia, lower half	Abrasion	44 months	Pain, 4 months
14	1939	Thomas	19 F	Right tibia, upper part	None	None	Swelling, 7 years; pathological fracture
15	1939	Rankin	25 M	Left tibia, lower part	Puncture wound	1 year	Pain, swelling, 1 year, 6 months
16	1940	Hebbel	14 F	Right tibia, lower part	None	None	Pain, swelling, 4 months
17	1942	Dockerty and Meyerding	21 F	Left tibia, middle part			Recurrent pain, 8 years; swelling, 4 years
18	1942	Dockerty and Meyerding	27 M	Left tibia, middle part	Abrasion	6 years	Recurrent fractures; pain; tumor
19	1942	Anderson and Saunders	45 M	Right ulna			Weakness of area, several months
20	1942	Bell	16 M	Left femur, lower part			Pain, 6 weeks
21	1944	Cagnoli	14 M	Left tibia, middle third			Pain, 4 months; swelling, less time
22	1947	Halpert and Dohn	24 F	Right tibia, juncture middle and lower thirds	Contusion; fracture		Pain, 2 years
23	1947	Meffley and Northup	16 F	Left tibia, juncture middle and lower thirds	Contusions		Swelling, 8 years; intermittent pain
24	1952	Mangalik and Mehrotra	40 M	Tibia, femur, inguinal glands	Contusion	1 year	Pain, 1 year
25	1953	Baker, Dockerty, and Coventry	35 M	Distal end of left tibia and fibula	None		Nodule, 6 years; pain, 2 years
26	1953	Baker, Dockerty, and Coventry	56 F	Right tibia			Swelling, 20 years; pain, 4 years
27	1953	Baker, Dockerty, and Coventry	27 F	Right tibia, lower part	Contusion	None	Lump, 8 years

bedded in paraffin, sectioned with a microtome, and stained with hematoxylin and eosin. Soft-tissue preparations were handled in a similar manner, except for the decalcification.

In the follow-up study, questionnaires were sent to all authors who had reported cases and to the patient or relatives in each of the five cases from the Mayo Clinic. In this

way, additional information was obtained in eighteen of the twenty-seven cases. In the remaining nine cases, either replies were non-informative or no replies were received.

NOMENCLATURE

The term "adamantinoma", which indicates a tumor consisting of enamel, is probably misleading. No enamel has been found in such tumors occurring in long bones, and some pathologists, for example, Robinson, have expressed doubt that it has been demonstrated in other locations. Ewing, in 1926, and Hampp, in 1942, stated that small portions had been found in jaw types. The term "ameloblastoma" indicates a tumor composed of or originating in the embryonal enamel-forming cells. Until enamel has been found in one of these tumors in the extremities, however, the term conveys an incorrect meaning.

Schulenburg emphasized the multiplicity of names when he listed no less than sixteen terms used in the early literature to refer to adamantinoma of the jaw.

Until more is known of the pathogenesis of this tumor, it would seem wise to refer to it as "adamantinoma (so-called)" of the long bones.

INCIDENCE

In the twenty-seven cases which form the basis of our study, there were sixteen males and eleven females. Petrov and Glasunow mentioned an additional three cases. The information in their paper or in the original articles was not sufficient to permit acceptance or rejection of the cases of Maier or Simon with certainty. Cases in which a diagnosis had been made but which had not yet been reported were mentioned by Lichtenstein and by Halpert and Dohn. The case reported by Casini is not included as an accepted case; it represents an epithelial tumor, with adamantinoma-like features, developing in a case of osteomyelitis with a draining sinus.

AGE

The youngest patient was a boy, twelve years old (Case 3), while the oldest was a woman, fifty-seven years old (Case 12). No characteristic age distribution was apparent.

SITE

The tibia was involved in twenty-five cases, and the femur, fibula, and ulna were involved once each. In addition, Mangalik and Mehrotra reported direct extension from the tibia to the femur, and the presence of coexistent lesions in the fibula and in the inguinal lymph nodes. Lichtenstein mentioned involvement of a radius in an unpublished case.

ONSET, DURATION, SIGNS, AND SYMPTOMS

The onset was with pain in fourteen cases. The duration of pain varied from one and a half months to seventeen years. Tenderness was the initial symptom in one case, with a duration of eight years. In seven cases a mass or a swelling first attracted the patient's attention, and the duration of this sign or symptom varied from three to seven years. In five cases the character of onset was not described.

PATHOLOGICAL FEATURES

Gross Characteristics

The gross appearance of this tumor, as described in the literature, has shown a wide variability. Gray or white has been the color, if mentioned, except in Rankin's case, in which it was described as reddish-brown. Mention is made of the external contour being smooth [3] and lobulated [26]. A capsule may be present [7, 13, 29, 36]. At times the consistency has been firm [10, 22, 29], brainlike [10], soft [4, 5, 17], elastic [23], and gritty [5, 30]. Some tumors have contained cystic cavities [4, 29, 36]. The contents of these have been straw-colored fluid [29] and blood [4]. The tumor may involve the cortex and periosteum [37], the marrow [14, 30],

TABLE II-A

TREATMENT AND FOLLOW-UP DATA: KNOWN FATALITIES

Case	Author	Bone Involved	Treatment: Initial	Treatment: Second	Treatment: Third	Initial Treatment to Follow-up	Other Data
9	Rehbock and Barber*	Tibia	Excision			1 year	Necropsy. Local recurrence. Metastasis to inguinal nodes; wound infection, septicaemia, hemorrhagic pancreatitis.
10	Oberling, Vermes, and Chevereau*	Tibia	Excision	7 months later: above-knee amputation		138 months	No necropsy. Bony excrescences on ribs prior to death representing metastases?
11	Dunne*	Tibia	Roentgen treatment	9 months later: above-knee amputation		105 months	No necropsy. Clinical and x-ray evidence of metastasis to inguinal nodes, lungs, hip, brain, and spinal cord.
15	Rankin*	Tibia	Curettement and roentgen treatment	1 year later: resection of shaft	17 months later: resection and bone graft‡	12 years	No necropsy. X-ray evidence of metastasis to lungs.
16	Hebbel*	Tibia	Curettement	15 months later: curettement	1 year later: above-knee amputation	69 months	No necropsy. 32 months from third treatment: local recurrence and x-ray evidence of metastasis to lungs. 10 months later, death.
17	Dockerty and Meyerding*	Tibia	Excision	16 months later: above-knee amputation		28 months	No necropsy. 1 year from second treatment: metastasis to inguinal nodes. Biopsy confirmed metastasis. 1 month later: sudden death, primary cause?
23	Meffley and Northup*	Tibia	Biopsy	19 months later: excision		50 months	No necropsy. X-ray evidence of metastasis to skull, pelvis, chest.
27	Baker, Dockerty, and Coventry	Tibia	Curettement	18 years later: bone graft	2 years later: above-knee amputation	23 years	No necropsy. 3 years from third treatment: abdominal exploration disclosed peritoneal metastasis. Primary? Death months later.

* The follow-up data in this case were kindly provided by the author in a personal communication.
‡ Case 15. Fourth treatment seven years later: below-the-knee amputation.

TABLE II-B

TREATMENT AND FOLLOW-UP DATA: KNOWN SURVIVALS

Case	Author	Bone Involved	Treatment			Initial Treatment to Follow-up
			Initial	Second	Third	
4	Baker and Hawksley*	Tibia	Excision	6 months later: below-knee amputation		21 years (July 1951)
5	Ryrie*	Tibia	Curettement	Few months later: above-knee (?) amputation		15 years (1947)
7	Holden and Gray*	Tibia	Excision	27 months later: excision and roentgen therapy	14 months later: curettement‡	20 years (July 1951)
8	Bishop*	Tibia	Curettement and graft	14 months later: below-knee amputation		16 years (1951)
14	Thomas*	Tibia	Curettement	1 month later: excision and bone graft	7 months later: above-knee amputation	14 years (July 1951)
18	Dockerty and Meyerding*	Tibia	Curettement	4 years later: excision	5 months later: roentgen therapy¶	18 years (June 1952)
21	Cagnoli*	Tibia	Excision and bone graft	39 months later: resection and bone graft		9 years (April 1951)
25	Baker, Dockerty, and Coventry	Fibula	Resection of fibula	2 years later: biopsy of tibia		3 years (May 1952)
26	Baker, Dockerty, and Coventry	Tibia	Above-knee amputation			5 years (May 1952)

* The follow-up data in this case were kindly provided by the author in a personal communication.
‡ Case 7. Fourth treatment eight months later: above-the-knee amputation.
¶ Case 18. Fourth treatment one and one-half years later: curettement. Fifth treatment nine years and seven months later: resection and bone graft.

or it may show penetration to the soft tissues [14, 28, 36]. The skin may be affected [3, 7]. Calcification may be present [2]. Particles of bone may be seen within the tumor [3, 23, 36]. In no case has the tumor contained a tooth or enamel.

Microscopic Appearance

In the reported cases, adamantinoma (so-called) of the long bones was diagnosed by the presence in the microscopic sections of one of the following three basic patterns or a combination of these.

TABLE II-C
TREATMENT AND FOLLOW-UP DATA: NO FURTHER DATA ON SURVIVAL

Case	Author	Bone Involved	Treatment			Initial Treatment to Follow-up†	Other Data
			Initial	Second	Third		
1	Fischer	Tibia	Resection and bone graft			8 months (1913)	
2	Pérochon and Veluet	Tibia	Amputation			Several months later (1928)	Metastasis to inguinal nodes proved by biopsy.
3	Richter	Tibia	Amputation			No follow-up (1930)	
6	Petrov and Glasunow	Tibia	Resection and bone graft			10 months (1932)	
12	Wolfort and Sloane	Tibia	Excision	16 months later: resection and bone graft		47 months (February 1938)	
13	Wolfort and Sloane	Tibia	Biopsy and radium treatment	13 months later: resection	1 year later: above-knee amputation	No follow-up in article (1938)	
19	Anderson and Saunders	Ulna	Resection and bone graft	62 months later: excision	2 months later: amputation of arm	13 years (1942)	
20	Bell	Femur	Biopsy			5 weeks	
22	Halpert and Dohn	Tibia	Above-knee amputation			Approximately 5 months postoperatively (April 1946)	
24	Mangalik and Mehrotra	Tibia	Inguinal-node biopsy	1 month later: biopsy of tibia	2 weeks later: above-knee amputation		Metastasis to inguinal nodes proved by biopsy.

† Only the patient in Case 20 was dead at the time of follow-up.

The first pattern consists of masses of epithelial islands in which the peripheral cells are columnar and arranged in a palisaded fashion. The central cells of these masses are stellate, producing reticulum formation. Within the center of the reticulum, cystic areas may exist. This pattern can be easily mistaken for adenocarcinoma. At times, the columnar peripheral palisaded cells appear to be lining a lumen, producing an alveolar arrangement.

The second pattern consists of islands of cells resembling basal cells, varying greatly in size and shape and scattered throughout a fibrous stroma. Palisading may again be a feature of the peripheral cells. Cystic areas may be present within the epithelial masses which are quite reminiscent of basal-cell carcinoma.

The third pattern consists of islands of squamous epithelium scattered throughout

TABLE III

EVIDENCE FOR METASTASIS IN ADAMANTINOMA

Author	Interval from Initial Operation to Metastasis	How Metastasis Was Diagnosed
Rehbock and Barber	1 year	Necropsy.
Dockerty and Meyerding	1 year	Inguinal lymph nodes examined.
Mangalik and Mehrotra	Encountered at initial operation.	Inguinal lymph nodes examined.
Nové-Josserand and Tavernier	2 years	Inguinal lymph nodes examined.
Dunne	94 months	Roentgenograms of hips, lungs. Clinically: regional nodes, spinal cord.
Rankin	11 years	Roentgenogram of lungs.
Hebbel	69 months	Roentgenogram of lungs.
Meffley and Northup	2 years	Roentgenograms of skull, pelvis, chest.

a fibrous stroma. Great variation in size and shape of the islands is found. Pearl formation is a feature.

A less common pattern, present in Cases 1 and 17, was characterized by the presence of islands of spindle cells. Meffley and Northup reported that the soft part of the tumor in their case suggested spindle-cell sarcoma.

In Cases 26 and 27, fibrous dysplasia was present and islands of epithelial tissue existed within these areas. Fibrous dysplasia was present without demonstrable tumor involvement in Cases 17, 18, and 25. The condition was strictly localized in all cases.

Pearl formation was reported in Cases 9, 10, 17, 20, and 26. The stroma throughout has been fibrous. Giant cells were present in Cases 4, 7, and 14. Vascularity at times was prominent (Cases 4, 20, and 21). The characteristics of the skin described by Dockerty and Meyerding in Case 17 have not been observed since: "The tips of papillary pegs appeared irregular and hyperchromatic. Here and there budding masses of basal cells were seen growing into the underlying subcutis. In short, the appearance was that of multicentric, basal cell carcinoma in situ."

An attempt to correlate the microscopic patterns with prognosis gave inconclusive results.

METASTASIS

There were four cases in which inguinal metastasis had been proved by tissue examination (Cases 9, 17, and 24, and the case of Nové-Josserand and Tavernier, quoted by Petrov and Glasunow). Also, in four cases there were changes in the roentgenograms indicative of metastasis (Cases 11, 15, 16, and 23). Unfortunately, necropsy could not be performed in these (Table III).

There is a possibility that the bony excrescences which developed in the case of Oberling, Vermes, and Chevereau (Case 10) represented metastatic tumors. It is also possible that the abdominal growths which occurred in Case 27 represented metastasis of the bone lesion.

Halpert and Dohn refer to a case of Dr. Henry F. Hunt in which metastasis supposedly occurred.

ROENTGENOGRAPHIC CHANGES

The roentgenographic appearance of so-called adamantinoma of long bones is not diagnostic and has varied considerably from case to case. In nineteen cases the appearance has been described as cystic or multicystic. Cortical expansion has been reported [3, 8, 26, 28].

Cortical destruction may occur [16, 22]. Periosteal reaction was present in four cases (Cases 4, 9, 10, and 16 .

PATHOGENESIS

Adamantinoma (so-called) of long bones consists of a primary epithelial tumor within bone. The pathogenesis is unknown. No agreement has been reached on the question of how epithelial tissue gets into bone in the first place. The two existing theories will be given subsequently.

Further disagreement surrounds the nature of the epithelial tumor. Is it actually a tumor identical with recognized adamantinoma of the jaw? Is it a basal-cell carcinoma with its known variations? Is it a squamous-cell carcinoma with its variations? Some of the reasoning toward answering each of these three questions will be briefly presented. Finally, what is the relation of this lesion to fibrous dysplasia?

1. In 1913, Fischer applied the name "adamantinoma" to a tumor occurring in the tibia, because he noted some similarities in the appearance of this tumor and adamantinoma of the jaw. The similarities included the gross appearance, the myxomatous connective tissue, and the palisading of basal cells. At variance were the features of mucous degeneration and the formation of gaps and clefts. He proposed that his case represented a primary epithelial tumor which took its origin from the embryonal epithelium of the enamel germ of the teeth. He explained the presence of the enamel germ in the tibia on the basis of its formation at the time of the tooth anlage, when ectodermal elements in the legs had the potentialities and the ability to develop into enamel epithelial anlage. The enamel epithelial anlage grows toward the bone and finally sinks in as it does in the jaw. Trauma may play a role in increasing the growth of the epithelial germ cell.

Fischer's observation must now be regarded with reservations. In listing the similarities between his tumor and adamantinoma, he mentioned mucous production and cleft formation. Both of these features, as emphasized recently by Bennett and King, may represent manifestations of synovial-cell specialization. Furthermore, Lauche, writing in 1947 and reviewing Fischer's material, concluded that the case referred to represented a synovial sarcoma and discredited the original observation by Fischer. It then seems reasonable to assume that the unique observation by Fischer was made on a tumor which might have been a synovial sarcoma.

The question then arose whether a synovial sarcoma could originate in bone. It seemed less difficult to accept a tumor derived from mesenchymal tissue arising in bone than one derived from ectoderm. Bennett and King discussed the variability of the microscopic pattern in synovial sarcoma and pointed out how an epithelium-like variant may occur. A second question was raised whether this entity could possibly represent an epithelium-like variant of synovial sarcoma. The five cases at the Mayo Clinic, as well as the cases in the literature, were further analyzed to determine if any evidence for this reasoning could be found. It was concluded that no marked similarity existed either clinically or miscroscopically.

2. Ryrie felt that at the time of injury basal cells are implanted into bone. Even when the skin is not broken, the trauma damages the deeper appendages of the skin and implantation results. He stated: "the reasonable explanation for adamantinoma of the tibia appears to be that in the region of the ossifying haematoma thwarted repair ultimately passes over into tumour growth".

Of the twenty-seven patients with this entity, thirteen had a contusion or an abrasion as the only known trauma. A fracture was mentioned in Cases 8 and 22 and a puncture wound in Case 15. No definite history of trauma was elicited in the other cases.

Thoma, in 1944, listed eight types of epithelial patterns which occur in adamantinomata of the jaw. Types 1, 2, 3, 4, and 8 essentially cover the microscopic variability of the adamantinoma-like tumors observed in the long bones. It would seem, therefore,

that so-called adamantinomata of long bones bear a microscopic resemblance to their cranial counterparts.

Is adamantinoma (so-called) a basal-cell carcinoma? Many authors,[13, 26, 27, 30, 32] writing on adamantinoma of the long bones, were impressed by the features of basal-cell carcinoma in their cases.

The microscopic features whereby the adamantinoma-like types were diagnosed do not distinguish them from basal-cell carcinoma. Ackerman and Regato stated in this regard that "the individual cells of the tumor masses frequently have a palisade arrangement of the peripheral cells. . . . These tumors can form solid masses, lacy strands, show foci of keratinization, or may show hair follicle origin. Rather infrequently they are cystic with areas of mucin."

Schulenburg emphasized the difficulty of distinguishing basal-cell carcinoma affecting the jaw, oral mucosa, skin, and antrum from adamantinoma of the jaw. He showed a photomicrograph of an adamantinoma continuous with the basal layer of the overlying epithelium. Dockerty and Meyerding had noted changes in the papillary pegs of the skin and masses of basal cells growing into the subcutis, giving the impression of basal-cell carcinoma *in situ*. No relationship was demonstrated between these downgrowths and the underlying bone tumor, but similar masses of basal cells existed within the bone tumor.

We sought to determine whether there is a relationship between basal-cell carcinoma of the skin and underlying bone tumor. Thirty cases in which a diagnosis of basal-cell carcinoma of the skin of the extremities had been made at the Mayo Clinic were studied. In only one case had a roentgenogram of the underlying bone been made. No change in the bone was evident. In the remaining cases it was assumed that there were no clinical symptoms suggestive of underlying bone disease.

Schulenburg concluded: "If the possibility of its origin from basal-layer cells is accepted, then the pathogenesis of adamantinoma of the tibia and ulna becomes clearer. It is then suggested that these tumours are examples of primary basal-celled carcinoma, originating from epithelial cells, either driven into the periosteum by trauma, or from embryonic cell-rests." "Although there is probably not sufficient evidence to state that adamantinoma is a basal-cell carcinoma, there are so many similarities in appearance and behaviour, that one might venture the suggestion that this type of growth now be known as 'primary basal-cell carcinoma of the jaw' (or any other bone, as the case may be)." The high incidence of metastasis in adamantinomata of long bones is a strong argument against this interpretation.

Is the tumor a squamous-cell carcinoma? Some [10] think that the neoplasms arise from squamous cells which dedifferentiate into modified ameloblasts. Such dedifferentiation could account for the various tumor patterns: basal-cell carcinoma, adenocystic basal-cell carcinoma, squamous-cell carcinoma with pearl formation, ameloblastic proliferation consisting of peripheral cylindrical cells, intermediate cells, central stellate reticular cells which frequently undergo degeneration to form cysts, and finally oval cells in a diffuse or sarcomatoid pattern. On this basis, the observed tendency for the tumor to metastasize finds ready explanation.

One further point in relation to the squamous-cell dedifferentiation is the case reported by Casini, in which a tumor developed at the site of a draining sinus. Under usual circumstances this tumor would be a squamous-cell carcinoma. Casini noted, however, that features similar to those in adamantinoma were present.

3. What is the relation of adamantinoma to fibrous dysplasia? There are now five cases in which these conditions are known to have coexisted. Tumor tissue was demonstrable in areas of fibrous dysplasia in two of the cases in this series (Cases 26 and 27) and absent in three (Cases 17, 18, and 25).

The fibrous change is always of the localized rather than the disseminated type and the bones affected are usually those which also harbor the neoplasm. In some instances a

bone adjacent to that affected by the adamantinoma is the site of fibrous dysplasia. Whether the latter results from tumefactive compromising of nutrient vessels or from other causes is not known at present.

TREATMENT

The results of treatment in the series of cases which form the basis of this study are summarized in Tables II-A, II-B, and II-C.

Of the twenty-seven cases, only the nine making up the group of known survivors allow the drawing of conclusions based on the type of treatment and the known period of survival. Of these nine patients, eight had lived five years or longer. Five had undergone amputation within approximately one year of the initial operation. In Case 7, four years and one month elapsed before amputation. In Case 26, amputation was the initial operation. Below-the-knee amputation was performed in Cases 4 and 8. Above-the-knee amputations were performed in the other four cases, survivals to the present being five, fourteen, fifteen, and twenty years. Three patients were not treated by amputation, with survivals to the present of three, nine, and eighteen years. In two of these cases, resection and bone-grafting were performed, and in the other, resection of the distal third of the fibula was performed. With the exception of Case 26, in which amputation was the initial therapy, it is worthy of note that all surviving patients treated initially by curettement or local excision had recurrence except the patient in Case 25, in whom an extensive resection of the involved fibula was performed.

In analyzing the eight cases in which death occurred, we are at once impressed by the fact that necropsy was performed in only one case. However, presumptive evidence of metastatic disease as the cause of death existed in Cases 10, 11, 15, 16, and 23. Regional metastatic lesions were known to exist at the time of death in Case 9, but, as stated previously, infection was interpreted at necropsy as the primary cause of death. Regional metastasis was proved by biopsy to exist six weeks prior to death in Case 17, and here again, the exact cause of death was unknown. In Case 27, there is only the scanty information that metastatic peritoneal involvement existed prior to death. It is at once obvious that any correlation between the type of treatment and the length of survival would be justly open to criticism.

Recurrence after roentgen therapy or after a local surgical procedure is a prominent characteristic of this tumor. In all eight cases in which the disease proved fatal, there had been recurrence. Of the nine known surviving patients, there was recurrence in seven. In Cases 25 and 26 there was no recurrence; radical resection of the fibula was the initial therapy in one and amputation in the other. In Case 21, the patient was surviving, with local treatment, after nine years, but recurrence had been evident after three and one-quarter years. In Case 18, the patient, surviving eighteen years, had a recurrence four years after initial treatment, and although exploration was carried out subsequently on two occasions, no further recurrence was found. Of the seventeen patients on whom follow-up data were obtained, nine had recurrence within two years and fifteen had recurrence later. Of the entire series of twenty-seven patients, seventeen are known to have had recurrence.

The evidence above indicates that roentgen therapy and radium therapy to the present have been of no value. Furthermore, recurrence is almost certain to follow an initial local surgical procedure. This is emphasized by the fact that only in Cases 25 and 26 was there no record of recurrence. It would therefore seem reasonable, when the diagnosis has been established, to amputate proximal to the involved bone.

There will be those who, on analyzing the group of known survivals and the number of years of survival before death in some of the group of known fatalities indicated in Table II-A, will argue for a single local excision, followed by amputation if recurrence takes place. There is not a sufficient number of cases on record at this time to discredit definitely the

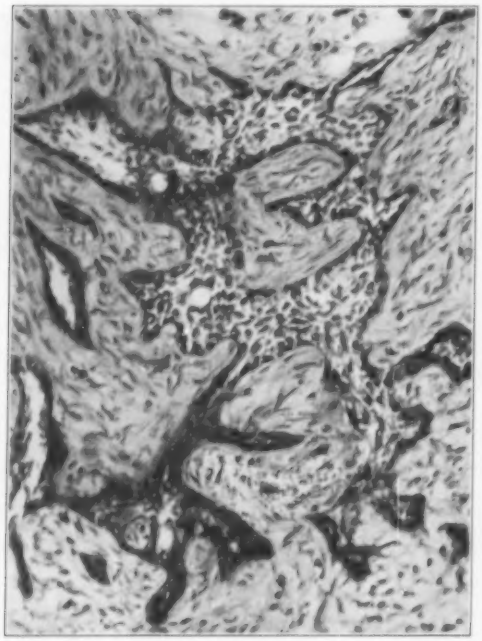

FIG. 1-A

Fig. 1-A: Case 25. Section from an adamantinoma (so-called) of the left fibula. There are epithelial islands with peripheral palisading and central reticulum formation, surrounded by a fibrous stroma (× 215, hematoxylin and eosin stain).

Figs. 1-B and 1-C: Roentgenograms of the left tibia before operation. There are multiple osteolytic areas and sclerosis involving the distal third of the shaft. The distal part of the fibula had been resected previously.

FIG. 1-B FIG. 1-C

above argument. The authors, however, do not favor delaying amputation except in the rare case in which an entire bone may be removed. The evidence indicates that amputation will always be ultimately necessary. When, as in Cases 9 and 17, metastatic lesions are known to have been present at twelve and thirteen months respectively after a local procedure, there is no assurance that a similar course will not be followed in the case in which one elects to delay amputation.

Why was amputation not performed in Case 25 at the second surgical procedure? At that time, there was no proof of recurrence; two years and one month had passed since the initial procedure, done elsewhere. Also, the significant facts brought out by the present survey were not at our disposal. Should this patient, at any of his periodic examinations, show evidence of recurrence, he will be advised to undergo amputation.

Reports of the three new cases from the Mayo Clinic (Cases 25, 26, and 27 in Tables I, II-A, and II-B) and follow-up reports on Cases 17 and 18 follow.

REPORT OF CASES

CASE 25. A white man, thirty-five years old, came to the Mayo Clinic on April 12, 1951, on the advice of his physician, who recently had noted a honeycomb appearance in the roentgenogram of the distal end of the left tibia. In 1943, while bathing, the patient had noted a tender, fixed nodule approximately 0.5 centimeter in diameter lying proximal to the left lateral malleolus and apparently attached to bone. The pain increased, and in June 1949, the patient consulted a physician who made a roentgenogram of the left leg, noted changes in the fibula, and referred him to a surgeon.

On June 29, 1949, a section nine centimeters long was excised from the distal end of the left fibula. A

diagnosis of adamantinoma was made.* The gross specimen of the fibula was described as consisting of a segment with a fusiform swelling in the middle portion. The cortex was thinned out and the medullary canal was filled with a gray, relatively soft tissue in which yellow areas of necrosis and softening were seen.

Figure 1-A shows a field selected from one of the original fibular sections on which the diagnosis had been based in 1949. Throughout the sections, the trabeculae of the cortical bone were separated by a fibrous stroma. Osteoclastic destruction was a prominent feature. Less frequently, osteoblastic activity with osteoid formation was seen. The stroma consisted of loose, interlacing bundles of fibrous tissue. Giant cells were present. Blood vessels were noted frequently. As is evident in Figure 1-A, the epithelial islands were characterized by cuboidal and columnar palisading at the periphery and reticulum formation toward the center. Cystic areas within the reticulum were frequently observed.

The roentgenogram of the left tibia made before operation showed some areas of decreased density. By April 1951, changes suggestive of extension were believed to be occurring and the patient was referred to the Mayo Clinic. His general health throughout had been good and he had experienced no loss of weight.

The results of physical examination on admission were within normal limits. The alkaline phosphatase measured 2.6 Bodansky units and the serum phosphorus 2.9 milligrams per 100 cubic centimeters. The roentgenogram showed multiple areas of rarefaction and sclerosis in the distal third of the left tibia (Figs. 1-B and 1-C). The distal third of the fibula was absent. On July 12, 1951, an extensive biopsy specimen taken from the distal end of the left tibia showed fibrous dysplasia but no adamantinoma. The patient had no evidence of roentgenographic change in this tibia as of January 1954.

Case 26. A white housewife, fifty-six years old, was admitted on January 20, 1947, with the primary complaint that she had been unable to walk on her right leg for the previous five months. She had first noted a symptomless swelling of the upper end of the right shin in 1927. From then until 1943, she had experienced gradual enlargement and swelling of this site. In 1943, she sustained a simple and uncomplicated fracture through this region. No specific history of trauma was obtainable. The fracture healed after immobilization in a plaster cast.

During the interval from 1943 to September 1946, there was gradual onset of pain limited to the upper part of the right shin. At times this became incapacitating and was accompanied by a sensation of insecurity—a feeling that her leg was going to give way. Toward the end of this period the patient started using crutches.

Fig. 2-A Fig. 2-B

Case 26. The roentgenograms showed an expansile, polycystic lesion at the juncture of the upper and middle thirds of the right tibia.

During October 1946, a lesion developed over the site of swelling of the right shin. This was described as being similar to a boil which gradually increased in size. An opening developed, but there was no history of drainage. On weight-bearing, she experienced a grinding sensation in the same region. She thought she had been afebrile, and she had had no loss of weight. She had received a course of roentgen therapy which consisted of 200 r per treatment given three times a week for a total of 2,000 r. Factors used were 200 kilovolts, ten milliamperes, filters of two millimeters of copper and one millimeter of aluminum, and a distance of fifty centimeters. Roentgenograms which had been made in July 1946 showed an expanding, polycystic lesion at the juncture of the upper and middle thirds of the right tibia (Figs. 2-A and 2-B). The cortex was markedly thinned and expanded. Running throughout the lesion was a strut of bone which appeared to be the remains of the old shaft. There was honeycombing within the larger cyst, and periosteal elevation was present on the lateral aspect.

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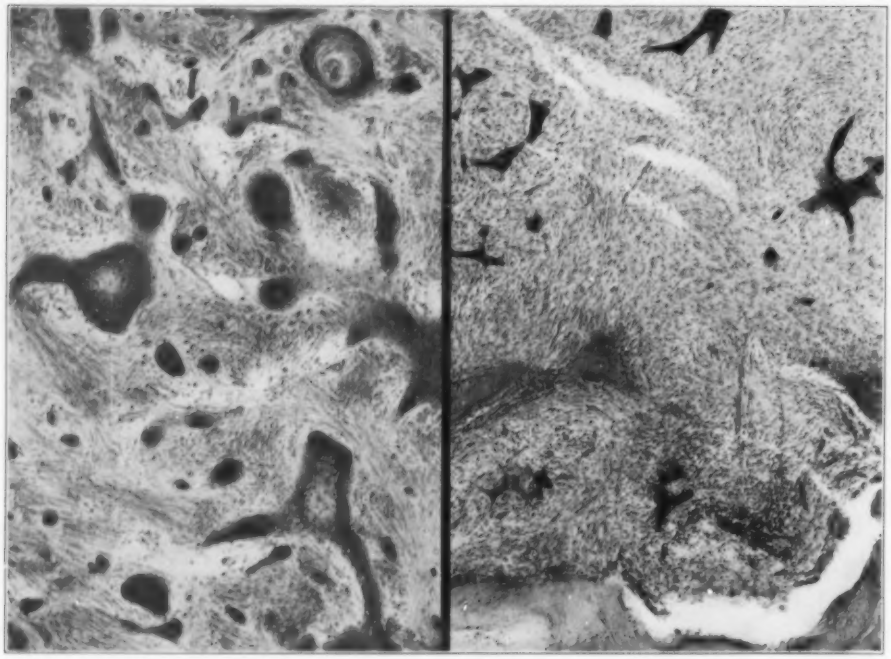

FIG. 2-C FIG. 2-D

Fig. 2-C: A section (× 65, hematoxylin and eosin stain) from the same lesion. Squamous epithelial islands show pearl formation and are surrounded by a fibrous stroma.

Fig. 2-D: Another section (× 55, hematoxylin and eosin stain), showing adamantinomatous tissue scattered throughout an area of fibrous dysplasia.

Physical examination on admission, in January 1947, revealed a palpable enlargement of the proximal third of the right tibia which was hard, tender, and immovable. Pressure over the swelling produced crepitus and was accompanied by pain. At the apex of the enlargement an area of red, soft tumor tissue existed. The right leg was swollen and oedematous. No fibular involvement or any enlargement of the inguinal nodes was detected. The alkaline phosphatase measured 3.1 Bodansky units. Roentgenographically, the chest appeared normal, while the right leg presented essentially the same appearance as that shown in Figures 2-A and 2-B, with the exception that additional cortical destruction was present.

Two days after admission, biopsy was performed and a diagnosis of adamantinoma was made. The extremity was amputated through the distal third of the femur. Pathological examination of the specimen disclosed that at the juncture of the proximal and middle thirds of the tibia a mass measuring five by six by twelve centimeters projected anteriorly and involved the overlying soft tissues. The tumor tissue was gray and firm and cut readily. The predominant epithelial appearance is shown in Figure 2-C where squamous epithelium with prominent pearl formation is evident. The stroma consists of bundles of fibrous tissue. Figure 2-D shows a field which is representative of the proximal and distal edges of the tumor as determined by gross examination. The trabeculae are separated by a fibrous stroma. Osteoblasts are active, with osteoid formation evident along the trabeculae. Islands of squamous epithelium are scattered throughout the fibrous stroma. Here then is an area of fibrous dysplasia with islands of tumor tissue scattered throughout. Sections cut at six centimeters proximal to the tumor and at six, thirteen, and twenty centimeters distal to the tumor showed normal cortical bone.

On May 19, 1952, the patient reported that she had been in good health, with no cough, no loss of weight, and no development of local masses.

CASE 27. A woman, twenty-seven years old, came to the Mayo Clinic in 1916 stating that eight years previously she had received a blow on the right shin. Since then there had been a progressive increase in the size of a tumor in this location.

Physical examination revealed a diffuse enlargement of the right tibia in the lower third. The initial roentgenogram was interpreted as showing a large tumor involving the lower end of the right tibia with no

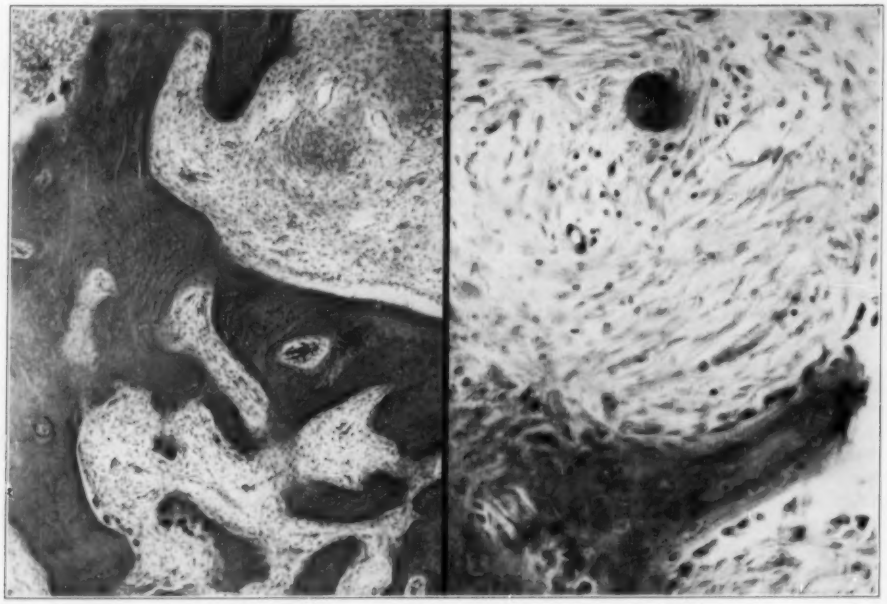

FIG. 3-A FIG. 3-B

Fig. 3-A: Case 27. Photomicrograph (× 65, hematoxylin and eosin stain) of a specimen from the distal part of the right tibia, showing fibrous dyplasia. The trabeculae are separated by a fibrous stroma which fills marrow spaces.

Fig. 3-B: Photomicrograph (× 220, hematoxylin and eosin stain) of an adamantinoma (so-called) in an area of fibrous dysplasia.

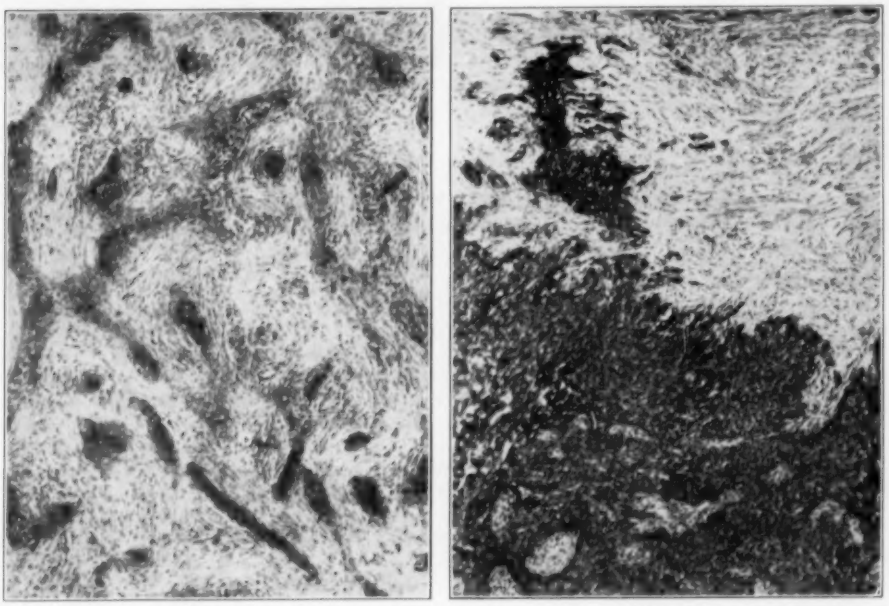

FIG. 3-C FIG. 4

Fig. 3-C: Photomicrograph (× 98, hematoxylin and eosin stain) showing an adamantinoma (so-called) from the distal part of the right tibia. Epithelial islands of cells resembling basal cells are scattered throughout a fibrous stroma.

Fig. 4: Case 17. Spindling cells resembling squamous cells involve a left inguinal lymph node and are metastatic from an adamantinoma (so-called) of the left tibia (× 65, hematoxylin and eosin stain).

rupture or elevation of the periosteum; it was believed that the lesion was probably a cyst. Four days after admission the involved site was explored surgically. According to the surgical notes, the lesion was considered to be a cyst growing into the lower part of the right tibia and involving about four inches of bone. The cavity was well lined and was filled with a fibrous mass, which was thoroughly curetted. Both side walls were fractured surgically and were bent over to fill the cavity. The clinical impression was that of a benign tumor.

The initial pathological interpretation was that of a peculiar tumor of bone which looked more like a fibrosarcoma than any other type of tumor.

The gross specimen available to us consisted of gray bone chips. In the microscopic sections the appearance of fibrous dysplasia was present (Fig. 3-A). Trabeculae were separated by a fibrous stroma. Adamantinomatous islands of tumor tissue were seen frequently within areas of fibrous dysplasia, as shown in Figure 3-B. The islands varied greatly in size and shape, being composed of small cells. The picture was typical of the so-called basal-cell variant of adamantinoma (Fig. 3-C). Mitotic figures were seen infrequently. The stroma consisted of dense, coarse strands of fibrous tissue. Giant cells were very common.

Eleven months postoperatively, slight tenderness was noted over the medial malleolus. Roentgenograms still showed cystic degeneration of the distal end of the right tibia.

In 1934, a bone-graft operation on the right tibia was performed elsewhere, followed, in 1936, by a Gritti-Stokes type of amputation. In 1939, at an operation performed elsewhere, a tumor adherent to the anterior abdominal wall was found. Peritoneal implants were present. The surgeon felt that the primary lesion was probably ovarian, but there was no pathological confirmation. The patient died in September 1939; no postmortem examination was made. There is, therefore, no way of knowing whether the abdominal tumor with malignant implants was in any way related to the tibial tumor.

FIG. 5-A FIG. 5-B

Case 18. Roentgenograms showing an osteolytic lesion at the juncture of the middle and distal thirds of the left tibia which involved the anterior and medial cortex and was interpreted as a recurrence of adamantinoma (so-called).

The subsequent course in Case 17 (Table I), which was reported initially as Case 1[10], is described below.

CASE 17. In November 1942, about one year after an amputation through the lower third of the left femur, the patient consulted her home physician because of enlargement of the left inguinal nodes of two months' duration. He removed the nodes, which were reported to be "cystic." They were interpreted by one of the authors (Dockerty) as presenting evidence of adamantinomatous epithelioma. Figure 4 shows the epithelial islands of spindling squamous cells involving the lymph nodes of the groin. The patient died suddenly December 11, 1942, from what was interpreted clinically by her attending physician as an embolus. Permission for necropsy was not granted.

In this case an accepted metastatic tumor was found thirteen months after amputation.

The follow-up data in Case 18 (Table I), which was reported initially as Case 2[10] are given below.

CASE 18. The patient was examined every two years after his discharge in September 1940 and no changes were evident. By January 31, 1950, aching had continued to increase and was associated with stiffness of the left knee. Pitting oedema and tenderness existed over the operative scar. The roentgenograms

were interpreted as showing a recurrence. An osteolytic lesion measuring about one by one by two centimeters had developed at the juncture of the middle and lower thirds of the tibia. Mottling existed in the osteolytic area. The medial cortex showed ragged destruction, and the lesion was expanding the cortex (Figs. 5-A and 5-B).

Amputation was recommended but was declined. Subsequently, the patient consulted another physician* who, on March 2, 1950, excised from the tibia a portion which was nine centimeters long and included the anterior three quarters of the circumference of the tibia; this was followed by bone-grafting.

The authors believed that the microscopic section which they had the privilege to observe showed fibrous dysplasia, and that there was no evidence of recurrence.

Eleven months later, when the patient returned to the Mayo Clinic, he was wearing a brace. Roentgenograms disclosed that the bone chips implanted at the previous operation were consolidating. Two localized transverse zones of rarefaction existed, which suggested incomplete stress fractures.

Approximately fourteen months after his last visit, the patient reported that he was in good health and that he was experiencing no symptoms referable to the operative site.

This report, then, represents a time interval of thirty years from the original contusion and eighteen years from the initial operation.

SUMMARY AND CONCLUSIONS

This paper reports on a study of twenty-seven cases of adamantinoma (so-called). Twenty-four of these, including two from the Mayo Clinic, were encountered in a review of the literature, while the other three consisted of new Mayo Clinic cases reported in detail in this paper.

In this series, the age of the patients ranged from twelve to fifty-seven years. The tumor involved the tibia in twenty-four cases, the femur in one, the ulna in one, and the fibula in one. Pain was the principal symptom. A mass and swelling were present in a few cases. Fibrous dysplasia coexisted in five cases.

Extracranial adamantinoma is a slow-growing epithelial tumor which occurs in bone. The origin of the epithelial tissue is unknown. No agreement has been reached as to whether the epithelial tumor is a basal-cell or a squamous-cell carcinoma. There has been no sex predominance. Microscopically, variations may include the following patterns: basal cells, adenocystic basal cells, squamous cells, an ameloblastic or a sarcomatoid pattern. The treatment of choice is amputation, preferably through the more proximal bone. This opinion is based on the fact that the tumor is almost certain to recur. In seventeen of the twenty-seven cases in this series, recurrence is known to have taken place, followed by death in eight instances. Metastasis was proved by biopsy in four cases, further emphasizing the necessity for radical surgical treatment.

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SPONGIOSA TEST OF BONE GRAFTS FOR TRANSPLANTATION

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The transplantation of bone offers manifold biological problems which have not been fully solved. For this reason the limits of the usefulness of the bone bank have not yet been determined. It is essential that we find the answers to the following questions:

1. Does the transplanted graft survive as a whole, in part, or not at all?
2. What determines the difference in the incorporation of autogenous, homogenous, or heterogenous bone tissue?
3. Should the graft be preserved as living bone, or is its devitalization during preparation useful in diminishing biological intolerance?
4. Which of the various methods of preservation is the best?

FIG. 1

The spongiosa grafts are cut out by means of the tube-shaped punch and may be inserted as indicated. (Reproduced by permission of Springer Verlag from *Langenbecks Archiv und Deutsche Zeitschrift für Chirurgie*, **273**: 854, 1952.)

The success of the bone bank has proved its usefulness. This paper is intended to delimit its indications. If we were inclined to elaborate these on the basis of clinical experience alone, however, we would have to expect many failures. A reliable test is needed which would enable us to determine to what extent grafts of different origins and prepared in different ways are suitable for transplantation.

The experimental methods used heretofore were bound to be unsatisfactory, as the results did not always correspond to results in clinical experience. The latter has taught us that fresh autografts are superior to all others. Whenever we have at our disposal a bed without regenerative power, such as the site of a pseudarthrosis, we are forced to rely on autogenous grafts. If, however, we place a graft into a bed with strong regenerative powers, as in the case of bone cysts, even necrotic heterogenous grafts will be incorporated and become replaced. In animal experiments, however, most authors have concluded that essentially there is no difference between the incorporation of a fresh autograft and that of a preserved homograft (homoiograft), and some workers have found no difference in the time needed for incorporation.

In all of these experiments the grafts were inserted into artificial defects in bone. Inclan, in 1942, found that preserved grafts were incorporated without reaction. Bush and Garber, in 1948, transplanted autogenous and homogenous iliac bone into both sides of the ilium in rabbits. They compared fresh and preserved autografts with fresh and preserved homografts; they found no fundamental difference in the manner of incorporation, but did find minor differences in the time needed for incorporation. They set up a "healing index" for the following types of grafts: fresh autografts, autografts deep-frozen for seven days, autografts deep-frozen for fourteen days, fresh homografts, autografts deep-frozen for twenty-

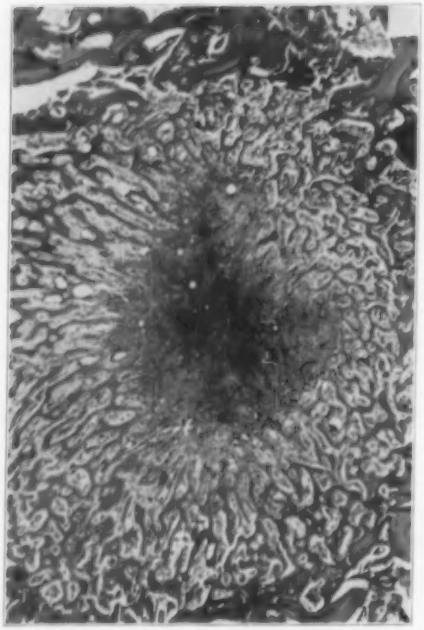

FIG. 3

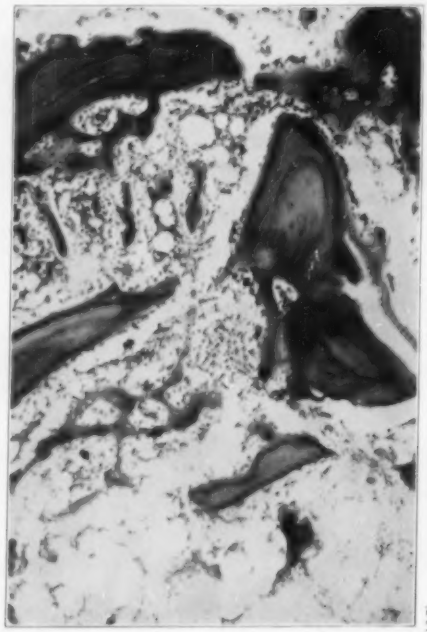

FIG. 5

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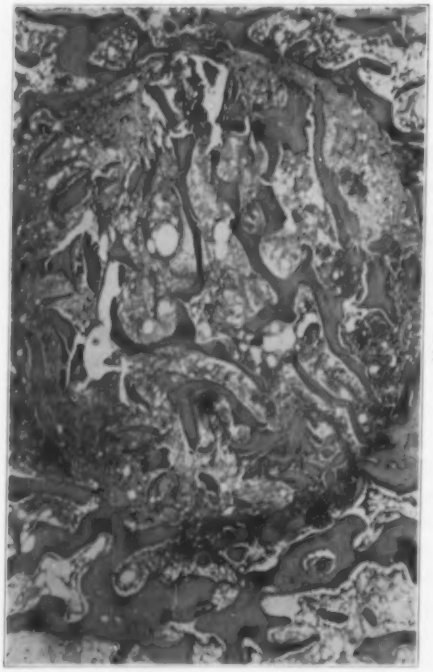

FIG. 2

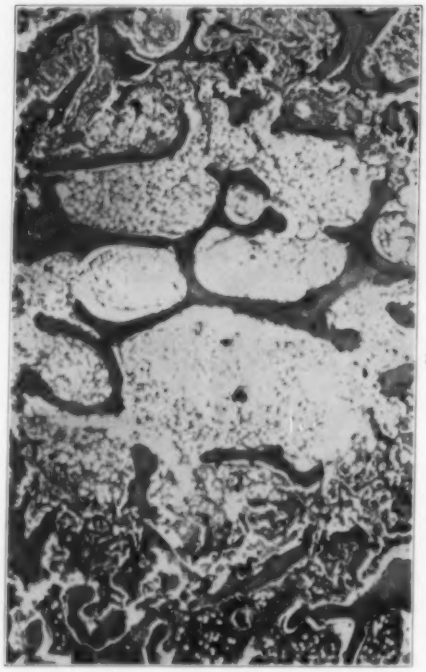

FIG. 4

Fig. 2: Transverse section (× 12) through a spongiosa bed and a devitalized homograft eight days after implantation. The implanted graft has been well received by the host, which has strong regenerative powers.

Fig. 3: "Hole test", made ten days after a plug of bone had been removed. No graft had been inserted, so that the pure productivity of the host was demonstrated (× 12).

Fig. 4: Photomicrograph (× 12) made eight days after implantation of a fresh heterogenous graft. At the peripheral zone, formation of callus is impeded and the implanted graft is lying in the site without any reaction.

Fig. 5: Photomicrograph (× 75) showing peripheral zone from the same section. There is poor formation of callus and poor creeping substitution.

eight to eighty-four days, homografts deep-frozen for seven to eighty-four days, boiled autografts, and boiled and deep-frozen homografts. Reynolds and Oliver in 1950 observed bone grafts implanted in the tibiae of dogs at intervals of one to ten weeks. They found no evidence that any elements of fresh autografts survive and concluded that the process of fixation and replacement is initiated by host tissue entirely. The first phase of healing was somewhat shorter in fresh autografts, but the authors believed that this was due not to activity of the graft but to less host reaction. In boiled grafts, however, the process of replacement was definitely delayed. Guilleminet, Stagnara, and Dubost-Perret, in 1950, implanted grafts taken from calves into defects of the radius of dogs. At thirty and at sixty days they found that both the frozen heterogenous grafts and the autogenous grafts used as controls had undergone fixation and replacement. Fresh heterogenous implants, however, acted like aseptic foreign bodies. Wilson in 1951 created lateral defects in the ulnae of dogs and found that fresh autogenous grafts produced callus earlier than did preserved homogenous grafts. After twelve weeks, however, there was no longer any difference between the two types of grafts. He also implanted spongiosa chips into the upper end of the ilium. The replacement of the transplanted spongiosa took place much more quickly than that of cortical grafts. Kreuz and his associates placed grafts in the radii of dogs. Roth, in experiments with femora of rabbits and dogs, examined the specimens thirty to sixty days after the transplantation of fresh autografts and preserved homografts; he was not able to detect any difference in union. He also filled drill holes in the upper portion of the tibia with spongiosa transplants and found no difference in either the manner or the time of union.

The numerous experiments in the transplantation of bone made at the turn of the century are of more than merely historical interest. At that time the question was how to evaluate fresh autogenous, homogenous, or heterogenous grafts until, with the success of fresh autografts in Lexer's and Macewen's work, scientific interest in these problems declined. At that time, as well as today, one group of authors (Barth, Marchand, Fischoeder, Pascale, Valan, and Baschkirzew and Petrow) were of the opinion that the grafts undergo necrosis whether they are preserved or fresh, autogenous or homogenous, and that replacement takes place through the activity of the host, while the other group (Ollier, Macewen, Axhausen, Saltykow, and Lexer) ascribed a definite activity to the living autograft.

The examination of grafts implanted in soft tissues, that is, in places which we describe in clinical terms as host tissue incapable of providing replacement, seems suitable for bone-bank bone only under special conditions. In general we may say that only fresh autografts can form bone in muscle.

Callus formation arising from metaplasia of host tissue has been described by many authors both earlier and recently in experimental transplantation of bone to muscle and to the anterior chamber of the eye. This callus formation, however, does not appear until much later and we may say that, in clinical practice, it will play only a minor role in the fate of an implanted graft.

In testing the value of a transplant from the clinical point of view, we must consider the mutual relation between graft and host, as well as the osteogenetic power of the graft and the site, in order to judge the mutual furtherance or hindrance. We must free ourselves

FIG. 7

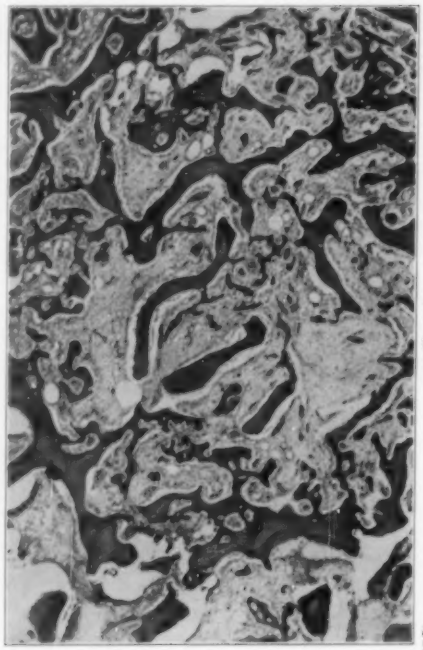

FIG. 9

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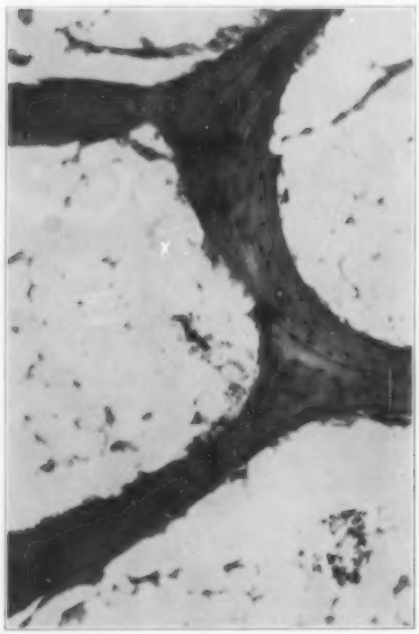

FIG. 6

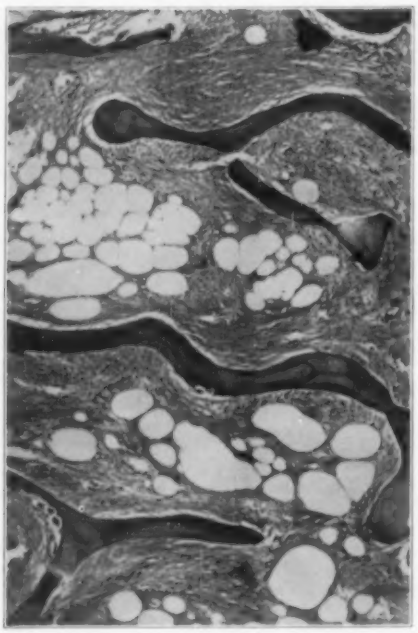

FIG. 8

Fig. 6: Photomicrograph (× 75) of the center from the same section. The implanted graft has not changed; it still shows stainable nuclei in the lacunae.

Fig. 7: Photomicrograph (× 100) of a section from a fresh heterograft, made ten days after implantation. Cell detritus and inflammatory reaction are evident; the trabecula still shows stainable nuclei.

Fig. 8: Photomicrograph (× 60) of a fresh heterograft at fourteen days. Connective-tissue envelopment of implanted trabeculae is evident. There is beginning resorption of connective tissue and decay by resorption.

Fig. 9: Photomicrograph (× 12) of a fresh homograft, made fourteen days after implantation. The over-all picture suggests minimal replacement by new bone.

from the conception that the periosteum plays a superior role in the healing of bone wounds. If we go into the bone, that is, into the spongiosa, we shall there find a site with regenerating powers which will almost always remain equally strong, so that uniformity of experimental conditions is relatively easy to obtain.

In 1951 the author developed the spongiosa test. The uniformity of experimental conditions in this test is assured by use of a tube-shaped punch by which holes five millimeters in diameter are cut into the spongiosa. The bone cylinders thus obtained, the diameter of which is smaller than that of the holes only by the thickness of the punch, may be easily reinserted or interchanged, either as living or as preserved bone (Fig. 1).

Figure 2 shows th over-all microscopic picture of the spongiosa test. The implanted graft, constant in its measurements, lies surrounded on all sides by host tissue which has strong regenerative powers and thus offers favorable conditions for early revascularization. By this means it will be possible to determine whether the small implanted graft is actively taking part in incorporation and replacement, whether its role is purely passive, or whether it produces a foreign-body reaction.

The possibility of performing several tests upon one animal at the same time offers a favorable basis for comparing results. The authors performed two tests at a time on the distal ends of both femora and the proximal ends of both humeri of a dog; in all, eight tests were performed simultaneously.

The technique of the operation is simple. It is performed under general anaesthesia and lasts only a few minutes. All the wounds healed by primary intention. Even on the first day after operation the dogs were not visibly hindered in their movements and they did not show any signs of pain.

EVALUATION

It is striking how easily the results of the spongiosa test can be evaluated. Some of the characteristics of preserved grafts can be determined with great accuracy. We did our best to consider all the factors which might be inquired into, but for the purpose of this report we will confine ourselves to the following three factors:

1. New-bone formation about invading blood vessels;
2. Creeping substitution;
3. Envelopment by connective tissue (foreign-body reaction).

The host response may be determined by the "hole test" (Fig. 3). The new bone tissue grows concentrically; there is a definite gradient. There is marked production of callus at the peripheral zone; farther in we see undifferentiated mesenchymal tissue; and in the very center there lies a hematoma. Implanted grafts which are made accessible only through activity of the host show this gradient more distinctly, not only in callus formation, but also in the process of creeping substitution. This is seen most clearly in the implantation of a heterogenous graft. Figure 4 shows the over-all picture; Figures 5 and 6 are high-power photomicrographs of the periphery and center respectively. The formation of callus at the peripheral zone is scanty; this would indicate that the transplant inhibits callus formation. The trabeculae of the heterograft are surrounded only by a narrow edge of bone formed by replacement. The rest of the graft has remained entirely inaccessible. It should be noted especially that the nuclei of the bone cells are still stainable.

As we continue to follow the fate of the heterogenous transplant, we frequently ob-

FIG. 11

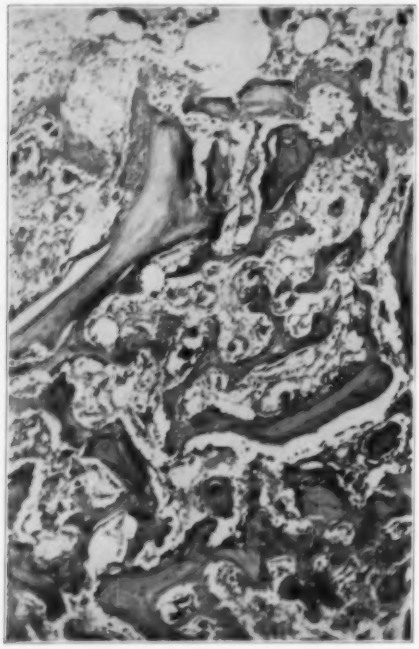

FIG. 13

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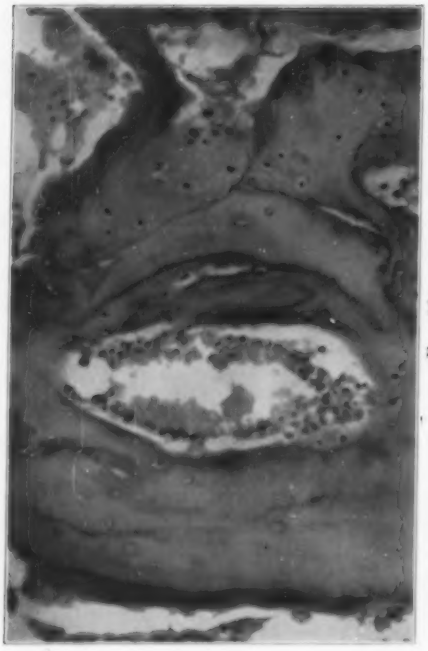

FIG. 10

FIG. 12

Fig. 10: Photomicrograph (× 50), showing peripheral zone from the same section as in Fig. 9. Extensive creeping substitution of the implanted trabeculae is evident.

Fig. 11: Photomicrograph (× 150) of the center from the same section as in Fig. 9. Only a narrow edge of replaced bone is evident. Figs. 10 and 11 demonstrate the decline in development from the peripheral zone to the center (× 150).

Fig. 12: Photomicrograph (× 12), showing the over-all picture of a fresh autograft eight days after implantation. The amount of new bone decreases from the peripheral zone, where there is productivity of both host and graft, to the center, where the graft alone is active. As Figs. 13 and 14 show, however, there is no difference in the quality of the production.

Fig. 13: Photomicrograph (× 60), showing peripheral zone from the same section as in Fig. 12. Marked callus formation and the beginning of creeping substitution are evident.

serve a stronger inflammatory reaction, with newly formed connective tissue and larger detritus masses between the trabeculae (Fig. 7). Finally the trabeculae are completely enveloped by connective tissue (Fig. 8) and will vanish through resorption of connective tissue; this process takes longer. Wherever osteoclasts take part in the process of osteolysis, however, there will also be formation of new fibrous tissue, as well as creeping substitution, and the grafts will be replaced through the strong regenerative powers of the host—that is, the spongiosa—although only after a period of delay.

The importance of the gradient in bone production in evaluating the results of the spongiosa test is particularly striking in the following example of a homograft. In the over-all microscopic picture (Fig. 9) marked new-bone formation is evident, but it decreases toward the center. With higher magnification the process of creeping substitution is seen still more clearly. At the peripheral zone it has progressed far (Fig. 10), while in the center (Fig. 11) only narrow edges of bone newly built by replacement are seen. Here again a distinct gradient in bone production is evident, which shows that the implanted bone will become replaced by the host. There is no indication of a stronger inflammatory reaction, however. We find no reason to suppose that the productive response of the host has been inhibited. The implanted graft allows good bony incorporation. This is the fundamental difference between homografts and heterografts.

An entirely new component part appears when an autograft is implanted. The over-all microscopic picture (Fig. 12) does show a slight decrease in the density of the newly built bone from the periphery to the center. In the high-power photomicrographs, however, there is visible at the periphery (Fig. 13), as well as at the center (Fig. 14), marked new-bone formation about invading blood vessels, as well as creeping substitution.

In order to judge the process correctly, it is necessary to examine the autogenous graft during the first few days after implantation. After four days all lacunae are empty (Fig. 15), which indicates that the bone cells will die.

At this stage, however, the dead trabeculae are already surrounded by osteoblasts and the first edge of new bone may be distinguished. This process takes place to the same extent both at the center and at the periphery. From this it may be concluded that some portions of the soft tissue of the autogenous graft survive and that the graft has the capacity to regenerate.

After this evaluation of the spongiosa test on the basis of three types of grafts—fresh heterogenous, fresh homogenous, and fresh autogenous—the authors proceeded to test two macerated (os purum) transplants, as these would allow a particularly clear insight into the use of the spongiosa test. Figure 16 shows a section from a macerated graft eight hours after transplantation. The areas from which soft tissue has been removed are filled with blood from the host. This points up the exceptional quality of macerated bone. When we note a temporary connective-tissue invasion, as may happen in the case of macerated heterogenous grafts, we may conclude that the specific proteins of the bone alone are responsible for incompatibility between the graft and the host, and this causes delay in replacement.

The effect of bone from which all organic substances have been removed is entirely different (Fig. 17). This is evident particularly in the center of the implanted graft. The

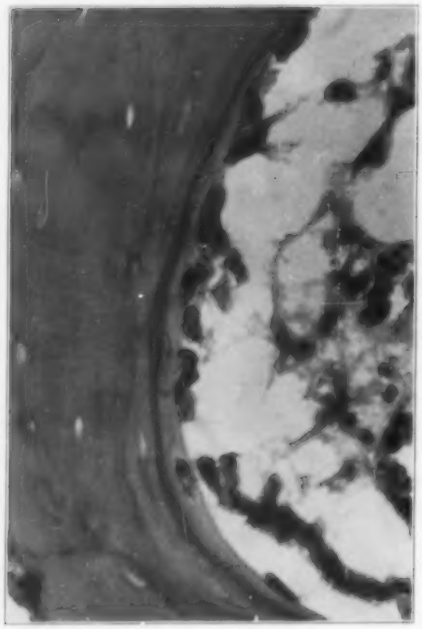

FIG. 15

FIG. 17

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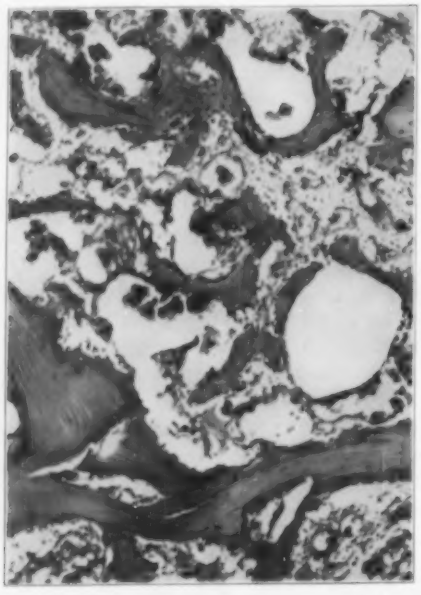

FIG. 14

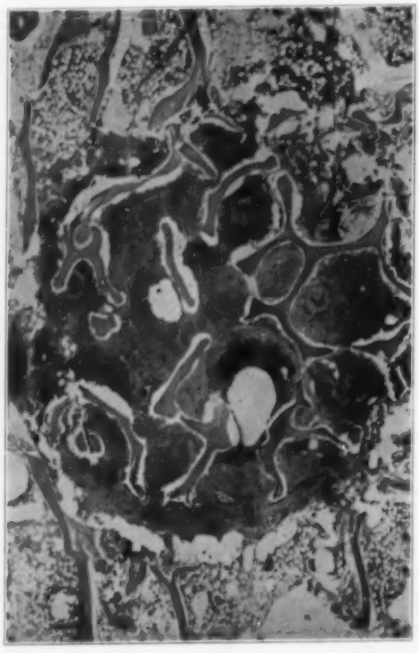

FIG. 16

Fig. 14: Photomicrograph (× 60), showing the center from the same section. Here, too, there is marked callus formation and the beginning of creeping substitution.

Fig. 15: Photomicrograph (× 420) of the center section from a fresh autograft, made four days after implantation. The lacunae are empty. Large cells of surviving soft tissue are attached to dead bone; thus the first edge of bone has been formed by creeping substitution.

Fig. 16: Photomicrograph (× 12), showing a section from a macerated heterogenous bone, eight hours after transplantation. The trabeculae are filled with host blood. (Reproduced by permission of Springer Verlag from *Langenbecks Archiv und Deutsche Zeitschrift für Chirurgie*, **273**: 855, 1952.)

Fig. 17: Photomicrograph (×75) showing center of a section from a heterogenous bone graft which has been freed of all organic substances, fourteen days after transplantation. The dark trabecula is all that remains of the implanted graft, which for the most part has been replaced by host bone tissue.

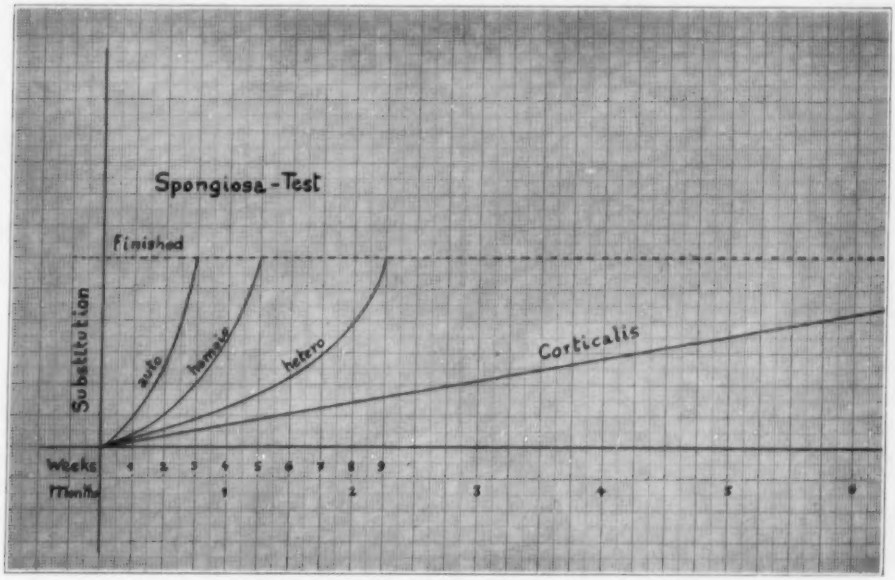

CHART I

The graph shows the time required for incorporation by living grafts. Homogenous grafts require somewhat less than twice the time needed by autogenous grafts; heterogenous grafts require three times as much time. Incorporation of cortical bone takes more time than incorporation of spongiosa.

graft, which consists only of inorganic substance, has for the most part been replaced by new bone. Callus formation and replacement surpass the norm by far. There is no trace of inflammatory reaction. The mineral elements of the bone incite the formation of callus and furnish it with building stones which exceed the function of a scaffolding.

RESULTS

To the present time the authors have evaluated 128 tests. The evaluator did not know the conditions of transplantation, so that his judgment was bound to be objective.

The spongiosa test reveals that the quality of replacement differs fundamentally in the various types of transplants. In each type of graft all completely formed bone cells will die. In fresh autogenous transplants, however, the soft tissue will survive and from it the graft regenerates. Only the living autogenous graft possesses the ability thus to regenerate.

The living homograft, on the other hand, is not able to regenerate itself, being dependent upon the osteogenetic potency of the host, and generally it will give way to replacement. The living heterogenous graft, however, complicates the process of incorporation. In most cases it is enveloped by connective tissue for a time only and becomes subject to osteoclastic resorption or to resorption by soft tissue, and is thus replaced by bone tissue from the host only indirectly.

The time required for incorporation and replacement in the various implanted grafts also differs greatly, as is revaled in the spongiosa test (Chart I). Living autografts require an average period of three weeks until all necrotic bone has been replaced. Living homografts require on the average twice as much time for replacement, while fresh heterografts are replaced by host tissue after nine weeks, that is, after an interval three times as long.

Fresh homografts show a wide range of variation in the response which they induce. In some cases they may be distinguished from living autografts only during the first few days. In other cases they resemble living heterografts and thus present a stronger foreign-body reaction. This points to the existence of type specificity. We hope to elucidate these questions by the spongiosa test, and further tests are now being made.

The devitalizing and preservation of an autograft results in a distinct inhibition in its incorporation. This is self-evident, as its ability to regenerate is thus removed. With heterogenous grafts, our experience has been that the devitalizing of the graft generally has a favorable influence on its replacement. Through the devitalizing process necessary for preservation, the foreign-body reaction of the host to the graft is decreased. In homografts the process of preservation may have unfavorable as well as favorable effects. This is understandable, as homografts resemble autografts in some respects and heterografts in others.

So far, no tests have been made in larger series to compare the different methods of preservation, although it is clear that the manner of preservation is of some importance. Deep-frozen grafts lose their viability entirely, but are nevertheless accepted easily by the host. The least desirable method of preservation is that of boiling. It should be stressed, however, that, whatever the method of preservation, the quality of autogenous or homogenous grafts is never influenced to the extent that they are incorporated as slowly as are the heterogenous grafts.

Macerated grafts hold an exceptional position. By maceration the host is spared the work of eliminating the soft tissue. However, the spongiosa test reveals fundamental differences between the incorporation of macerated heterografts compared with that of macerated autografts and macerated homografts. The grafts may be enveloped in many cases by connective tissue, a sign that they have not lost their protein-bound foreign-body reaction. Bone grafts which have been freed of all organic substance never show such envelopment by connective tissue. On the contrary, they are replaced by host bone with great rapidity.

SUMMARY

By use of the spongiosa test it is possible to determine the suitability for transplantation of different types of bone grafts. The differences between autografts, homografts, and heterografts are fundamental, both in the manner in which they are incorporated and replaced and in the time required for this process. Autografts regenerate from their own power; homografts are dependent on the osteogenetic power of the host; and heterografts for the most part are enveloped for some time by connective tissue and consequently act, to a considerable extent, as a foreign body in relation to the host.

In the spongiosa test, the site which has the strongest regenerating powers, the spongiosa, acts as the host. It is able to replace each of the different types of graft by its own osteogenetic potency. The time required for replacement by homografts is twice as much as that required by autografts, that required by heterografts is three times as much. Homografts thus have considerable versatility, sometimes resembling autografts and sometimes heterografts.

The devitalization of autogenous grafts inhibits their incorporation, while devitalization of homogenous grafts may further the process of incorporation.

Macerated grafts also show a protein-bound intolerance. Grafts consisting of inorganic substance—that is, freed from protein—definitely favor callus formation.

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PAROSTEAL (JUXTACORTICAL) OSTEOGENIC SARCOMA *

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A relatively rare bone tumor, parosteal osteogenic sarcoma, is characterized by a low degree of malignancy. This lesion has a marked predilection for the lower end of the femur, is attached to the cortex by a broad base, is ordinarily believed to be an atypical osteochondroma by the roentgenologist, and frequently confuses the pathologist by its subtle evidences of malignancy.

The problems posed by this type of tumor were first discussed by Geschickter and Copeland, who proposed the term "parosteal osteoma" in 1951. They had collected a series of sixteen cases, in thirteen of which they considered the lesion to be malignant. The clinical data supported their diagnosis of malignancy in most of these. Four of these patients had metastasis. Several of the remainder had recurrences which necessitated amputation, or they had a primary amputation. In some of their cases the follow-up periods were inadequate but the histories, in general, indicated the serious nature of this disease. Their series parallels very closely the one we shall present.

Jaffe and Selin, as well as Coley and Higinbotham, have described briefly a type of osteogenic sarcoma which has the features of those included in our study. The term employed by Jaffe and Selin, "juxtacortical osteogenic sarcoma", seems appropriate, but the equally accurate descriptive name "parosteal" deserves priority because of the major contribution on this subject—that by Geschickter and Copeland. Dr. Granville Bennett, presiding at a seminar on orthopaedic pathology at a meeting of the American Society of Clinical Pathologists in Chicago on October 16, 1953, presented an example of parosteal osteogenic sarcoma, indicating increasing acceptance of this entity.

Organizing hematomata, callus formation, heterotopic ossification as in myositis ossificans and in organizing hematomata, ordinary osteocartilaginous exostoses, and the recently described periosteal chondroma [11] are included among the juxtacortical lesions [2,3,5,6,12,13] which must be differentiated from the malignant tumor under discussion.

MATERIAL

In a detailed analysis of the benign and malignant bone tumors in the files of the Mayo Clinic, fifteen examples of parosteal osteogenic sarcoma were found (Table I). The original tumor in all of these cases was of a low degree of malignancy. In fact, the majority were considered to represent some benign process such as atypical osteochondroma at the time of the first excision (Table II).

In the cases included in our study the tumor did not seem to arise in a pre-existing benign lesion. Because of the implication by Lichtenstein [9] and by others that lesions of this type represent only a peculiar form of heterotopic ossification, a study was made of the eighty-nine cases of myositis ossificans diagnosed at the Mayo Clinic during

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TABLE I

PAROSTEAL OSTEOGENIC SARCOMA: SUMMARY OF CASES

Case	Sex and Age	Duration of Symptoms	Location	Type of Treatment and Date	Result
1	M 23	7 months	Distal end of femur	Local excision on April 25, 1919; Mid-thigh amputation on January 17, 1921; Disarticulation of hip,* August 1, 1921.	Postoperative death on August 4, 1921
2	F 29	6 years	Distal end of tibia	Local excision on July 17, 1925; Local excision, roentgen treatment on August 12, 1927; Amputation * on April 16, 1928.	Death from metastasis on February 14, 1943
3	F 30	12 years	Proximal end of humerus	Partial removal on June 28, 1935, Removal of remaining portion on September 3, 1935; Removal of recurrent tumor on October 29, 1935; Disarticulation of shoulder on September 2, 1941, Scapulectomy on October 17, 1942.	Death from metastasis on December 8, 1943
4	M 37	4 months	Distal end of femur	Local excision on October 26, 1935; Local excision on January 28, 1937.	Death from metastasis on February 23, 1940
5	F 38	6 months	Distal end of femur	Local excision on March 18, 1940; Amputation refused, x-ray treatment given on December 5, 1947; Amputation* on July 26, 1948.	Well on August 7, 1953 †
6	M 33	4 months	Distal end of femur	Local excision, x-ray treatment on April 22, 1940.	Well on August 7, 1953 †
7	F 41	44 months	Distal end of femur	Amputation on May 27, 1941.	Well on August 7, 1953 †
8	M 14	2 months	Distal end of humerus	Partial excision * on July 6, 1943; Resection of distal third of humerus, August 26, 1943.	Well on August 7, 1953 †
9	M 33	24 years	Distal end of femur	Amputation on April 30, 1945.	Well on August 29, 1953
10	F 36	14 years	Distal end of femur	Biopsy * in 1934; Partial excision * in 1936; Partial excision * in 1946; Amputation on July 6, 1946.	Death from unknown cause before 1954
11	F 12	3 months	Proximal end of tibia	Biopsy * in January 1949; Block excision on February 26, 1949; Local excision on September 9, 1950; Local excision on July 11, 1952; Local excision on September 19, 1953.	Large local recurrent lesion
12	F 14	14 months	Distal end of femur	Local excision * in August 1946; Local excision on July 5, 1947; Local excision on September 18, 1948; Amputation on November 26, 1949.	Well on August 7, 1953 †
13	M 29	7 years	Distal end of femur	Partial excision on January 30, 1950; Mid-thigh amputation on April 12, 1950.	Well on August 7, 1953†
14	M 46	1 week	Proximal end of humerus	Partial excision on April 7, 1952.	No roentgenographic signs of growth on August 7, 1953 †
15	F 14	9 months	Distal end of femur	Block excision on July 27, 1953. Amputation for recurrence, June 2, 1954.	

* Performed elsewhere. † Date of mailing follow-up letter to patient.

TABLE II

PAROSTEAL OSTEOGENIC SARCOMA: ORIGINAL DIAGNOSIS

Diagnosis		No. of Cases
Osteochondroma		6
Fibrous	1	
Cellular	4	
Degenerating	1	
Dense osteoma		2
Fibrosarcoma		2
Fibrochondro-osteosarcoma		2
Inflammatory sclerotic bone		1
Exostosis with formation of young connective tissue		1
Parosteal osteogenic sarcoma		1

a fifteen-year period ending in 1950. Recurrence was observed following surgical removal in several of these cases. This should be expected, because the trauma of removal is often probably at least as great as that which had produced the phenomenon originally. In none of these lesions, however, did we observe a tumor capable of progressive growth or one with any pathological evidence of malignancy. Furthermore, in the files of the Clinic we could find no example of osteogenic sarcoma arising in a focus of heterotopic ossification. Myositis ossificans, then, failed to qualify as a source of the lesion under discussion; this supported our impression that parosteal osteogenic sarcoma is a distinct entity.

CLINICAL FEATURES

Seven of the patients were males and eight were females. Their ages varied from twelve to forty-six years, the largest group being in the fourth decade. If the age at the time the mass was first noted is considered, however, the patients were about equally distributed among the age groups from ten to thirty-nine years (Table III).

An idea of the frequency of occurrence of this type of tumor is suggested by the fact that there are nearly 400 osteogenic sarcomata and a total of more than 2,000 primary bone tumors in the collection from which these fifteen tumors were obtained.

Ten of the fifteen tumors involved the distal part of the femur. Two affected the proximal and one the distal part of the humerus, one the proximal and one the distal part of the tibia.

Symptoms

The presenting complaint in each instance was the presence of a mass. The remarkable fact is that seven of the patients had noticed the mass for more than one year, and

TABLE III

PAROSTEAL OSTEOGENIC SARCOMA: AGE DISTRIBUTION

Age (*Years*)	Time of First Treatment (*No. of Patients*)	Time Mass Was First Noted (*No. of Patients*)
1 to 9	0	1
10 to 19	4	5
20 to 29	3	4
30 to 39	6	4
40 to 49	2	1

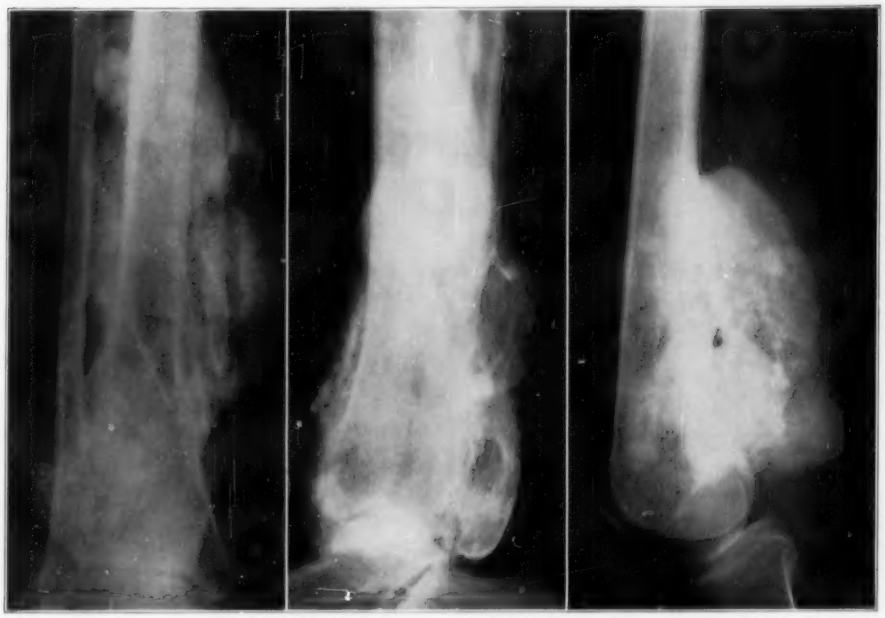

FIG. 1-A FIG. 1-B FIG. 1-C

Roentgenographic appearance of parosteal osteogenic sarcoma.
Figs. 1-A and 1-B: Original tumor in Case 2. Fig. 1-C: Case 13.

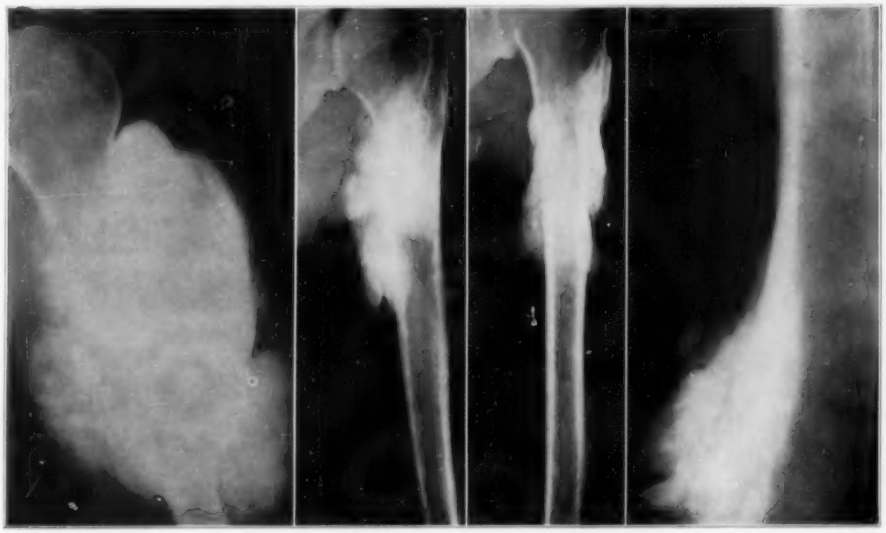

FIG. 1-D FIG. 1-E FIG. 1-F FIG. 1-G

Fig. 1-D: Original tumor in Case 3.
Figs. 1-E and 1-F: Preoperative appearance of the lesion in Case 14.
Fig. 1-G: Preoperative appearance of the tumor in Case 15.

five had known of its presence for periods ranging from six to twenty-four years. It is almost certain that the remaining eight patients had had the tumor for a considerable time before becoming aware of it.

Seven of the patients had noted no pain, while the remaining eight had noted mild pain of short duration. Only five patients had experienced loss of range of motion of the neighboring joint.

Physical Findings

A hard mass was palpated in all fifteen cases. Terms such as "diffuse", "fixed", and "surrounds bone" were encountered often in the original descriptions of the tumors. In only two cases was a notation made that pressure over the tumor was painful. Increased local heat was noted in six cases, and dilated vessels over the tumor were described in two. As previously stated, loss of range of motion was present in five cases, and, in each instance, the size and location of the tumor were the cause. Weight loss, anaemia, and other symptoms sometimes associated with malignant bone tumors were not present in these cases.

Roentgenographic Appearance

The typical tumor appeared as a dense lobulated mass attached to the metaphyseal region and sometimes also to the epiphysis of a long bone. All the tumors were attached by a broad base, and all but one were described as being sclerotic. In most cases, there were also areas of lesser density scattered throughout the tumor (Figs. 1-A, 1-B, and 1-C).

The tumor was usually lobulated. Its borders were ordinarily sharply defined but in some of the tumors the border was indistinct in those areas where it blended with the surrounding tissue shadows. As the tumor grew, it sometimes extended along the shaft, but it almost always tended to surround the bone. In some instances the latter process was complete, the shaft of the bone then running through the tumor (Fig. 1-D).

Reactive periosteal new-bone formation and medullary involvement were conspicuous by their absence in the primary lesions. In one case in which there was apparent medullary involvement in the primary lesion, the tumor was easily shelled off the cortex, leaving a smooth base. The circumferential growth of the tumor outside the cortex gave the erroneous impression in the roentgenogram of medullary involvement. Recurrent lesions often did show actual, and sometimes prominent, medullary involvement and exhibited obvious roentgenographic features of malignancy.

Gross Appearance

As observed in the roentgenograms, the tumors ordinarily had an irregular lobulated surface (Figs. 2-A, 2-B, and 2-C). They were bony for the most part but, with the exception of one case, softer areas of cartilage and fibrous tissue of variable size were present. The regular cartilage cap of an osteochondroma was absent. The surgeon's impression in seven instances was that the tumor was encapsulated by fibrous tissue which was firmly adherent to the mass. In several cases, however, muscle could be seen entering the tumor on gross examination. On cut section, the tumors were found to be composed of bone, fibrous tissue, and cartilage, intermixed. Again, the bony component usually predominated. Necrosis was not found in a primary tumor, although it was sometimes seen in recurrences with a higher degree of malignancy.

The recurrent lesions were usually less sclerotic than the original ones, fibrosarcoma often being the predominant component. Recurrent lesions tended to involve the medulla; when such involvement had occurred, the lesions could not be differentiated from ordinary osteogenic sarcomata without reference to the original lesion.

Microscopic Appearance

The microscopic appearance of this type of tumor was variable, yet in its basic components it was consistent. This appearance serves to establish the diagnosis which should be suspected after study of the history, the roentgenograms, and the gross appearance

FIG. 2-A FIG. 2-B FIG. 2-C

Gross appearance of parosteal osteogenic sarcoma.

Fig. 2-A: Amputation specimen in Case 13. The marrow cavity was completely free of tumor.

Figs. 2-B and 2-C: Gross appearance of the tumor in Case 15.

TABLE IV

PAROSTEAL OSTEOGENIC SARCOMA: GRADE OF MALIGNANCY (BRODERS' METHOD)

Case	Grade of Malignancy			
	Original Tumor	Recurrence		
		First	Second	Third
1	1	3		
2	1	1	?*	
3	1	1	2	3
4	1	1		
5	low 1	?*		
6	1			
7	1			
8	1			
9	1 to 2			
10	?*	?*	2	
11	1	1	1	
12	?*	1	1	3
13	1	1		
14	Not malignant?			
15	1	1		

* Operation performed elsewhere.

of the tumor. Perhaps foremost of the features observed was the presence of beams of non-malignant bone which surrounded spaces filled with atypical spindle or polyhedral cells; among these, occasional or sometimes fairly numerous mitotic figures were seen (Figs. 3-A to 3-D). These spaces were not filled with fat or normal hematopoietic cells, a fact which served clearly to differentiate this tumor from ordinary cartilaginous exostosis. These same atypical spindle-cell elements made up the fibrous areas of the tumors (Figs. 4-A to 4-D). Evidence of malignancy was present in only parts of many of these tumors, making multiple sections necessary for accurate appraisal of the lesions. In one case which we have included because of its roentgenographic and gross similarity to the others, there were no obviously malignant areas (Fig. 3-B).

Variable amounts of new osteoid were usually observed among the proliferating spindle cells. The larger zones of new osteoid frequently showed calcification. The smaller masses seemed to blend with the fibrosarcoma elements as though the latter were undergoing metaplasia to a type capable of producing osteoid (Fig. 4-B). This osseous transformation was occasionally marked, producing a sclerotic mass.

Islands of cartilage were seen throughout most of these tumors. Careful study at the periphery of the larger or smaller islands of cartilage usually revealed evidences of malignancy in the form of cells with plump nuclei and multinucleated cells (Fig. 4-C). The peripheral cartilage cells frequently blended with streams of spindle cells. The larger masses of cartilage often showed areas of calcification. Areas of chondrosarcoma were found in twelve of fifteen primary tumors and in all the recurrent tumors. Benign giant cells were an incidental component in eight of the primary lesions.

As shown in Table IV, the histological features of malignancy in all elements of these tumors tended to increase with recurrence. Finding satisfactory histological proof of malignancy was no longer difficult in the average recurrent lesion. The clinical behavior of these growths paralleled the increase in the histological grade of malignancy. Each primary tumor was of Grade 1 or low Grade 1 malignancy (Broders' method), except for the tumor in Case 14, in which it was impossible to find definite evidence of malignancy.

Sections from the periphery of the lesions disclosed muscle and fat cells trapped within the substance of the tumor in eleven instances (Fig. 4-D). This finding has led, no doubt, to the diagnosis of myositis ossificans in some cases of this type [9]. Although, as previously stated, a capsule was said to be associated with seven of the primary tumors,

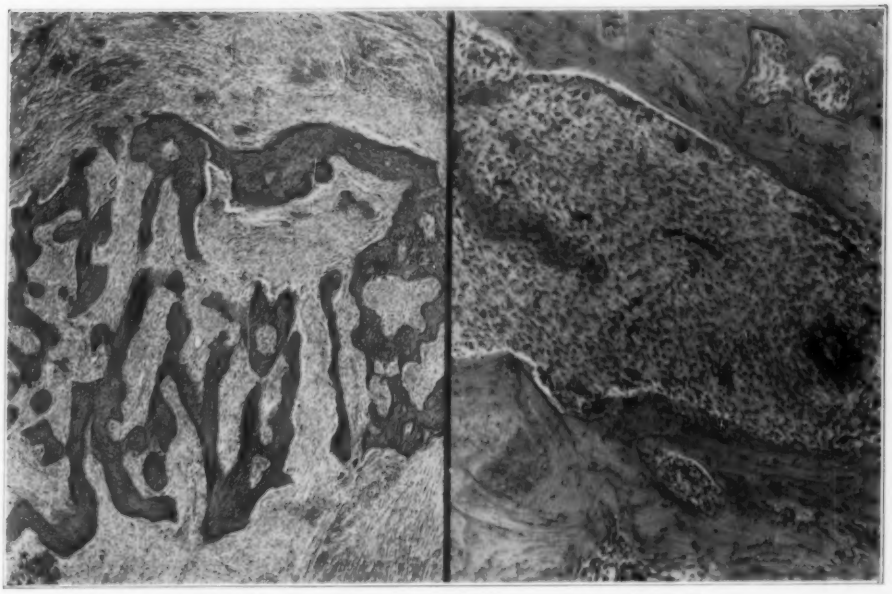

FIG. 3-A FIG. 3-B

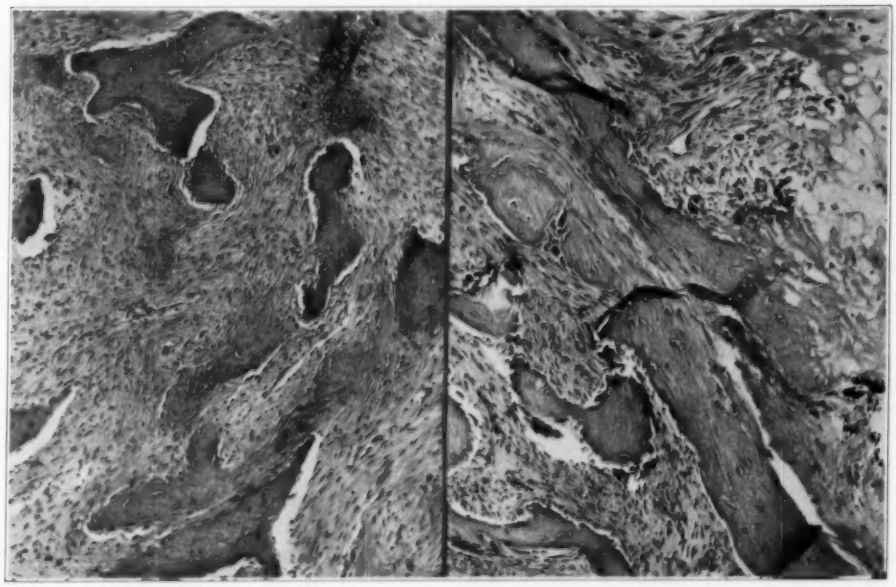

FIG. 3-C FIG. 3-D

Fig. 3-A: Section from the original tumor in Case 3, showing the arrangement of beams of benign bone. The spaces are filled with masses of spindle cells. This was the basic picture in every case reported. (× 30, hematoxylin and eosin stain.)

Fig. 3-B: Section from Case 14, showing non-malignant beams of bone and spaces filled with cellular but not obviously malignant fibrous tissue. Many areas similar to this were seen in most of the tumors. Note the darker strand of osteoid in the center of the fibrous zone. (× 80, hematoxylin and eosin stain.)

Fig. 3-C: Typical arrangement of bone trabeculae and spindle cells in Case 15. (× 100, hematoxylin and eosin stain.)

Fig. 3-D: Another section from the tumor in Case 15, showing the relationship of the cartilage islands to the other elements. (× 100, hematoxylin and eosin stain.)

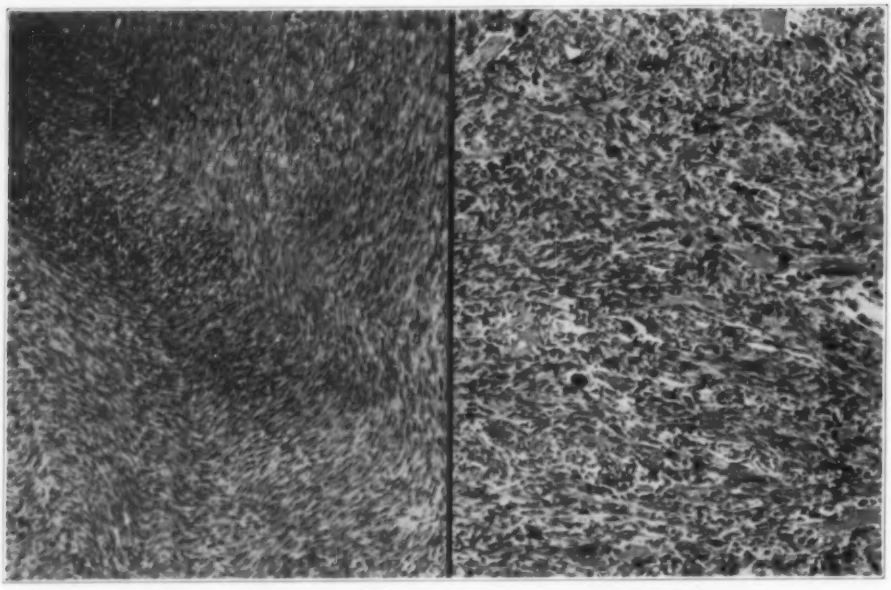

FIG. 4-A FIG. 4-B

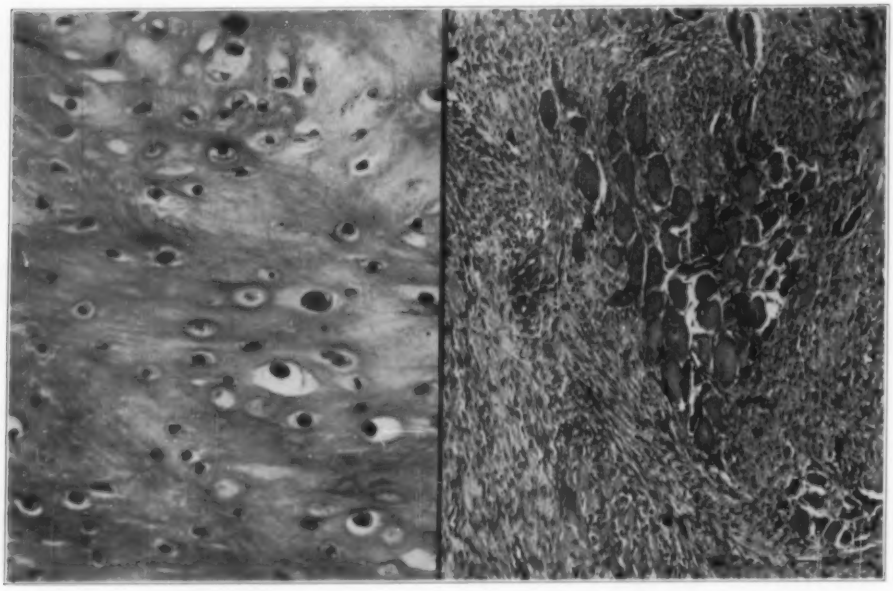

FIG. 4-C FIG. 4-D

Fig. 4-A: Section showing collections of atypical spindle cells in the recurrent tumor in Case 2. (× 80, hematoxylin and eosin stain.) Similar areas of this cell type were found in all but one of the primary tumors.

Fig. 4-B: Showing typical small collections of osteoid in Case 13. (× 100, hematoxylin and eosin stain.)

Fig. 4-C: Showing an island of chondrosarcoma found in the primary tumor in Case 12. (× 200, hematoxylin and eosin stain.) Malignant changes in cartilage were found in twelve of the fifteen primary tumors.

Fig. 4-D: Showing a group of muscle fibers trapped in the periphery of the tumor in Case 13. (× 80, hematoxylin and eosin stain.)

this finding was verified in but a single instance when the tumors were studied under the microscope.

Differential Diagnosis

1. The tumor under discussion is, we believe, a type of osteogenic sarcoma. It differs markedly, however, from the ordinary osteogenic sarcoma which is of a high degree of malignancy, grows rapidly, and almost always involves the medulla.

2. Osteochondromata and exostoses have a broad base in some instances, but the cortex of the bone is continuous with and forms part of the tumor. Their periosteal covering is intact, and muscle and fat are not trapped within their substance. The core of these tumors is continuous with and identical with the underlying medullary bone. The cartilage present is in the form of a cap rather than scattered throughout the tumor. Malignant change is rare in these lesions and usually occurs in the form of pure chondrosarcoma.

3. Chondrosarcoma, predominantly on the surface of bone, or periosteal chondroma must be differentiated from parosteal sarcoma. Such cartilaginous lesions lack the prominent bony and fibrous components of juxtacortical osteogenic sarcoma.

4. Heterotopic ossification, as in myositis ossificans, may occur adjacent to bone, and such ossified tissue may be rather adherent to the bone. Ordinarily, enough calcium is deposited within the tumor to make it appear sclerotic on x-ray examination. Characteristically this condition involves and is contained within a muscle, and hence is characterized by the trapping of muscle fibers throughout the tumor. In other cases the heterotopic calcification has no obvious relationship to muscle. It is well known that myositis ossificans in the florid phase and osteogenic sarcoma may appear similar microscopically. Points which help to differentiate such heterotopic ossification from juxtacortical osteogenic sarcoma include a history of short duration in the former. Myositis ossificans does not coapt itself to bone over a large area and, in fact, often does not even touch bone. Finally, the bone produced in these foci of heterotopic ossification shows an orderly pattern; this is completely lacking in the new osteoid produced in juxtacortical osteogenic sarcoma.

5. Active ossification (callus) in a healing fracture or in an otherwise injured bone should offer no real problem in differential diagnosis because in such cases the proliferating chondroid and osseous tissues exhibit no evidences of malignancy, especially at a cytological level. The markedly exuberant callus formation observed in some cases of osteogenesis imperfecta may be troublesome [1], but in these the clinical history will resolve the problem.

Treatment

Case 14 may be excluded from this discussion, since it is the one case in which definite evidence of malignancy is lacking; sixteen months after partial removal there was no evidence of renewed growth.

In twelve of the remaining fourteen cases the treatment consisted in local removal of the tumor. This was usually accomplished by removing it piecemeal with an osteotome. An apparent cure resulted in but one instance (Case 6). This patient was given a course of roentgen treatment postoperatively.

Partial excision was the primary procedure in four cases (Cases 3, 8, 10, and 13). In each of these four cases it was necessary to reoperate and all four patients eventually required amputation.

It was necessary to sacrifice the limb in ten cases. Of the other four patients, one died of metastatic lesions, one has been cured for thirteen years by local excision and roentgen therapy, one has been cured for ten years by block resection of the affected portion of the humerus, and one (Case 11) has recurrent tumor at the time of writing.

Five patients have died: three of metastatic growths, one three days after re-ampu-

tation for recurrence in the stump, and one of unknown cause. In retrospect, the primary tumors in these cases seem to be similar in every respect to those in the cases in which the host has survived. One patient died fifteen years after her amputation, with widespread metastasis confirmed at necropsy.

Of the eight patients who appear to be well without evidence of tumor, six have had amputation, one has had resection of the distal third of the involved bone, and one has had local excision and roentgen therapy. Roentgen therapy has been administered in two additional cases. It did not appear to have altered the course of either tumor.

Four of the cases selected as representative of the problems encountered in cases of parosteal osteogenic sarcomata are reported below.

ILLUSTRATIVE CASES

Case 2. A woman, aged twenty-nine, first seen at the Mayo Clinic on July 13, 1925, stated that a bony tumor had been present over the right medial malleolus for six years. Three roentgen treatments six months previously had failed to alter its appearance. She did not recall a serious injury to her leg. Her only symptom had been recent mild aching pain. Examination revealed a hard, fixed, non-tender tumor which appeared to involve the distal part of the tibia and fibula. Roentgenograms (Figs. 1-A and 1-B) were interpreted as showing an "old fracture of the tibia and fibula with marked bony overgrowth".

At operation the tumor was found to be nodular. Some of the nodules were separated from the main mass. The tumor was not encapsulated and, although it extended into the capsule of the ankle joint both medially and laterally, the bony cortex appeared to be normal after the tumor had been removed. Microscopically the tumor was interpreted as "multiple exostoses associated with marked formation of young connective tissue". Review of the lesion has shown the presence of low-grade malignancy in some of the sections.

The tumor recurred and it was removed by local excision two years later at which time the fibrosarcoma elements were prominent (Fig. 4-A). The patient received two courses of roentgen therapy. Amputation was performed elsewhere on April 16, 1928, because of a second recurrence. She remained well until March 1942, when she noted exertional dyspnoea. Roentgenograms made at that time revealed a mass in her lung. She died on February 14, 1943. Postmortem examination showed the lungs, liver, adrenals, ovaries, and peritoneum to be filled with osteogenic sarcoma. No primary site could be found other than the leg which had been amputated fifteen years previously.

Case 3. A thirty-year-old woman who came to the Clinic on June 25, 1935, had noted a tumor in the upper part of her left arm for the preceding twelve years. The tumor had been increasing in size for the preceding five years. She had not knowingly injured her arm. The only symptom had been occasional aching with changes in weather. Examination revealed an extensive, firm, fixed tumor which seemed to surround the bone. Roentgenograms disclosed a markedly sclerotic tumor which surrounded the upper third of the humerus (Fig. 1-D).

The tumor was removed in two stages, the first on June 28, 1935, and the second on September 3, 1935. The pathological diagnosis was dense osteoma. In studying many sections of this tumor we have found some malignant cartilage, spindle cells, and osteoid-producing cells. Many areas were benign in their appearance.

A third operation, to remove a small recurrent lesion, was required on October 29, 1935. Fibrosarcoma was discovered in these sections. The tumor returned slowly, and on September 2, 1941, the shoulder was disarticulated. After one year it was necessary to perform a scapulectomy. The tumor was considered to be Grade 3 at this operation. In spite of these efforts to eradicate the tumor, metastasis became evident and the patient died on December 8, 1943.

Case 13. A man, twenty-nine years old, stated on January 27, 1950, that he had noted a slowly growing mass behind his right knee for the previous seven years. He did not recall significant trauma. Recently he had experienced mild aching in the region of the tumor, which was relieved by local heat.

Examination revealed a tumor encircling the distal part of the femur at and above the level of the patella. The skin over the tumor was stretched and shiny. There was an increase in local heat. Although the tumor was generally hard, some areas of its surface felt like hard rubber. Flexion was limited at 120 degrees. A roentgenogram disclosed an extremely sclerotic tumor lying chiefly on the posterior aspect of the lower end of the femur (Fig. 1-C).

On January 30, 1950, subtotal excision was performed; it was impossible to remove more of the tumor without sacrificing the limb. The pathological diagnosis was multicentric fibrosarcoma arising in an osteochondroma. The remaining portion of the tumor continued to grow and a mid-thigh amputation was performed on April 12, 1950. At that time it was evident that the tumor was an osteogenic sarcoma (Fig. 4-B).

A report from the patient on August 7, 1953, stated that there was no evidence of recurrence and that his general health was good. It is too early to be certain that he will not have recurrence or metastasis.

CASE 14. A man, aged forty-six, came to the Mayo Clinic on March 15, 1952, because of a swelling of his left arm which had been noted one week previously. Examination disclosed a hard fixed growth on the medial aspect of the proximal part of the humerus. Roentgenograms disclosed a dense bony tumor (Figs. 1-E and 1-F). On April 7, 1952, most of the tumor was removed. Grossly this lesion contained no soft areas, but microscopically its basic pattern was very similar to that of the group under discussion. Interlacing trabeculae of bone were separated by rather cellular fibrous tissue (Fig. 3-B) which was undergoing osseous metaplasia in some areas. This lesion was not obviously malignant, and roentgen examinations made at frequent intervals during the sixteen months following subtotal excision have failed to show evidence that the remaining tumor tissue is growing.

COMMENT

The present-day concept of bone pathology includes recognition of the fact that each neoplasm must be considered as a clinicopathological entity. A combination of clinical and roentgenographic as well as gross and microscopic pathological features is often essential for the proper evaluation of a neoplasm. This is particularly true in the rarely seen and difficult diagnostic problems posed by parosteal osteogenic sarcoma.

We believe that this lesion is malignant from its inception; hence we prefer to call it "parosteal osteogenic sarcoma" rather than "parosteal osteoma", as the latter term fails to indicate the true nature of the disease. There is no evidence, from this series, that the tumor arises in some pre-existing benign lesion. It is true that the primary tumor in some of these cases presented only minimal evidences of malignancy. In fact, we have included one example (Case 14) in which we cannot satisfy our criteria of malignancy. We feel that, even so, this patient will very likely get into more serious difficulty from the lesion.

The slow development of the malignant clinical course of juxtacortical osteogenic sarcoma is readily explained by the low degree of malignancy histologically. This tumor, in that respect, bears a similarity to the soft-tissue tumors called "extra-abdominal desmoids" which are composed of fairly well differentiated cells but have a marked tendency to recur even after wide local excision. This similarity extends to the property of invasion and envelopment of surrounding soft tissues commonly observed in both neoplasms, although in desmoids apparently the degree of malignancy is not so prone to increase with recurrence as in juxtacortical osteogenic sarcomata.

A decision regarding the proper mode of treatment of this type of tumor must be based on the known fact that in most of the cases (nine out of ten in this series) the lesion recurs after local excision. If the tumor is of an extremely low degree of malignancy, one is tempted to institute conservative treatment, saving amputation for those of increased malignancy. The hazard of such procrastination is well illustrated by Cases 1, 2, 3, and 4, in all of which death resulted from the effects of such recurrences. The best program of therapy will probably become evident only after more cases have been collected, but the available evidence indicates that early amputation is the treatment of choice.

SUMMARY AND CONCLUSIONS

On the basis of a study of fifteen cases of parosteal osteogenic sarcoma, we concluded:

1. Parosteal osteogenic sarcoma is a recognizable clinicopathological entity which is unusual because of its low degree of malignancy. The history and roentgenographic appearance should lead the surgeon and the pathologist to suspect the diagnosis. Careful histological examination will confirm it.

2. In the past this type of tumor has commonly been believed to be a benign one, such as atypical osteochondroma or a strange recurring form of myositis ossificans. It is the authors' opinion that the lesions are usually malignant from the beginning.

3. The statement that "each neoplasm has its own . . . criteria governing benignity or malignancy" [11] is again emphasized in respect to this tumor.

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TRAPPING OF THE POSTERIOR TIBIAL TENDON AND INTERPOSITION OF SOFT TISSUE IN SEVERE FRACTURES ABOUT THE ANKLE JOINT

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The most important single cause of disability in fractures about the ankle joint is the failure to achieve anatomical reduction. This is all too often due to one of the following reasons: (1) a tendency on the part of many to be satisfied with "an almost satisfactory reduction", (2) insufficient courage to tell the patient that a second or third manipulation may be necessary, (3) a desire to spare the patient additional anaesthesia, and (4) failure to obtain roentgenograms made in true anteroposterior and lateral planes. Roentgenograms which are not made in true anteroposterior or lateral planes can well be misleading in evaluating mortise alignment.

Closed manipulation for fractures and dislocations about the ankle joint is usually satisfactory. More rarely, open reduction is necessary in certain early or fresh fractures in which a mechanical derangement exists which involves bony impingement, trapped soft tissue, or inaccessibility of smaller fragments to manipulation by closed methods. A failure

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to obtain reduction with closed manipulation should be handled with fortitude, and surgical reduction should be carried out while the fracture is still fresh from injury, before superficial skin necrosis, oedema, and other vascular manifestations occur. Those cases which are deferred for elective repair invariably have a poorer functional prognosis. Some of the indications for early surgical reduction are described as follows:

1. Single or comminuted fractures which involve one third or more of the anterior or posterior tibial articular surface, with displacement or rotation of the fragment, which are not reducible on closed manipulation. These often include a portion or the whole of the medial malleolus.

2. Fracture-dislocation of the ankle, as described by Bosworth, in which the upper fibular fragment is caught behind the posterolateral ridge of the tibia. This must ordinarily be subjected to open reduction with a pry before the mortise alignment can be restored.

FIG. 1-A

Case 1. Roentgenograms show fracture of the lateral malleolus with disruption of the mortise.

FIG. 1-B

FIG. 1-C

Fig. 1-B: After two manipulations, the fracture was still unreduced.

Fig. 1-C: Mortise alignment was restored after the removal of the posterior tibial tendon from the joint and after repair of the deltoid ligament.

To these may be added:

3. Severe fracture-dislocations of the ankle in which soft-tissue structures, that is, ligaments, tendons, nerves, or vessels, may become trapped within the ankle mortise or between fragments of bone and prevent the restoration of mortise alignment by closed manipulation.

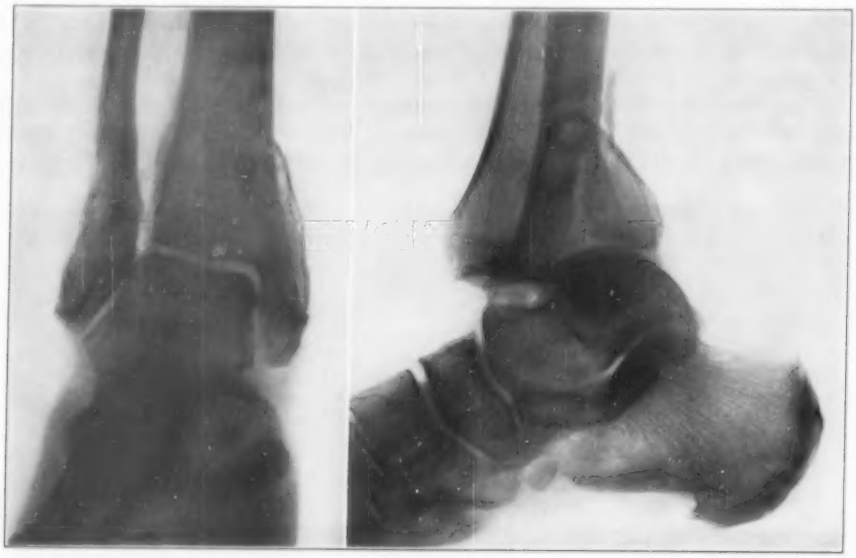

FIG. 2-A

Case 2. Roentgenograms show large fragments of the posterior and medial aspects of the medial malleolus, as well as posterior dislocation of the ankle.

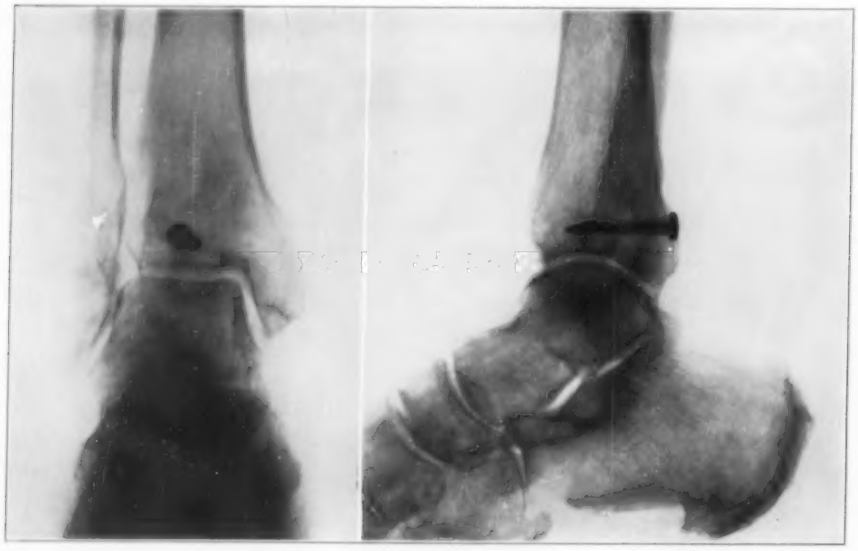

FIG. 2-B

Roentgenograms made seven months after the operation. The operation had consisted in the extraction of the posterior tibial nerve and tendon and the fixation of the fragments by means of a single metal screw.

This situation has been mentioned by Lee and Horan who have given a description of many of the obstacles to reduction of fractures about the ankle by closed methods. Bennett has for many years taught the recognition of such possible complications in ankle fractures. Case reports of such mechanical derangements are not found in the literature or in many of the current textbooks on fracture treatment. Undoubtedly the condition has been responsible for unsatisfactory results when there has been a failure to recognize the mechanical displacement. This report briefly summarizes four cases of severe fracture-dislocation of the ankle joint; in two of these, the posterior tibial tendon was found irreducibly trapped at the time of open reduction, and in two cases there was interposition of the deltoid ligament within the joint mortise.

CASE 1. A colored man, forty-two years old, was admitted to Lincoln Hospital, Durham, for open reduction of a severe Pott's fracture of the ankle, after two attempts at manipulation under anaesthesia had

FIG. 3-A

Case 3. Roentgenograms show severe trimalleolar fracture before manipulation.

FIG. 3-B

The fracture remained unreduced after manipulation.

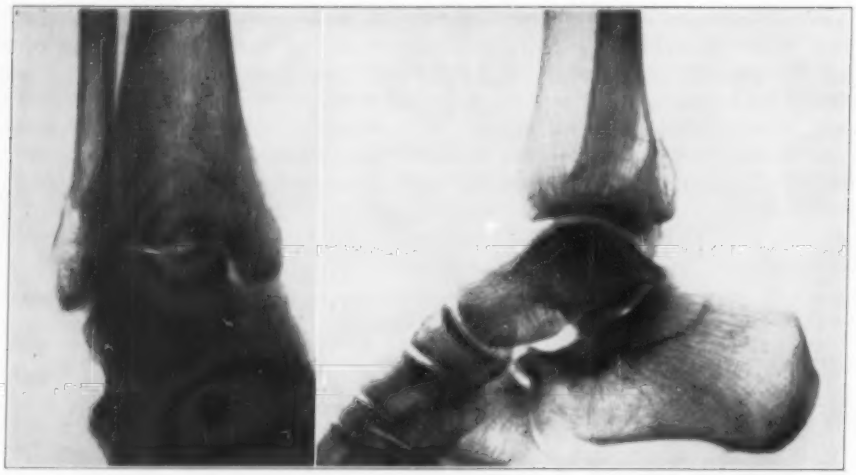

FIG. 3-C

Mortise alignment was corrected after open reduction and the extraction and repair of the trapped portion of the deltoid ligament.

failed to restore mortise alignment. At operation, the posterior tibial tendon was found to be trapped within the joint, having slipped through a complete tear of the deltoid ligament and under an intact medial malleolus. This prevented the medial reduction of the laterally displaced talus. Undoubtedly no amount of manipulation would have corrected this mechanical impediment. The deltoid ligament was repaired beneath the tendon, and the reduction required no force for maintenance. Six months after removal of the cast, the patient walked without pain or limp and demonstrated a range of motion equal to that in the opposite ankle.

CASE 2. A white woman, forty-two years old, was admitted to Watts Hospital, Durham, for open re-

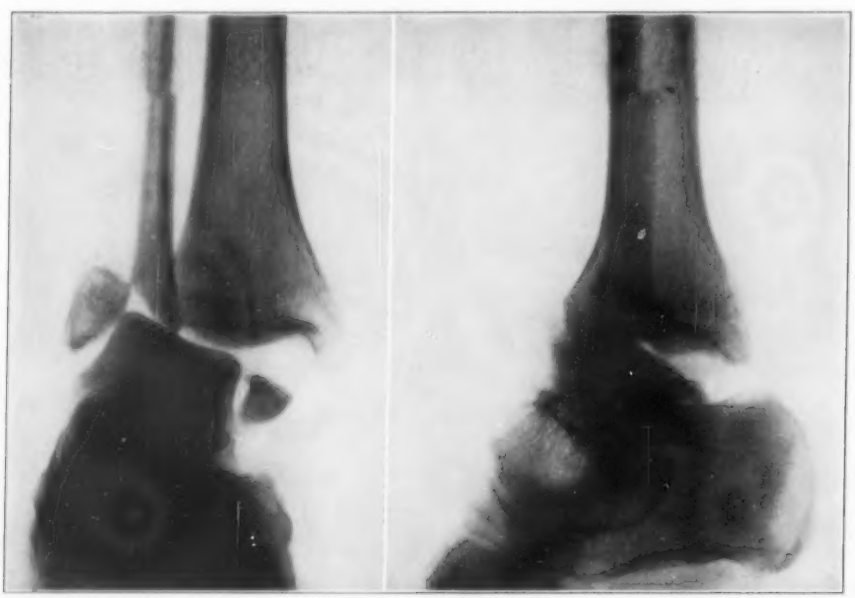

FIG. 4-A

Case 4. Roentgenograms show severe trimalleolar fracture of the ankle joint before manipulation.

duction of a posterior fracture-dislocation of the ankle, with large displaced fragments of the posterior and medial malleolus which extended through the groove for the posterior tibial tendon. When seen in the emergency room, the patient complained of severe pain radiating into the great toe with any movement of the ankle. At operation the posterior tibial tendon and nerve were both found trapped between fragments at the fracture site. The fragments were repositioned anatomically beneath the tendon, fixation was achieved with a single metal screw, and mortise alignment was restored. Examination nine months later revealed a full range of ankle motion and a history of mild discomfort in damp weather.

FIG. 4-B

The fracture remained unreduced after repeated manipulations and after skeletal traction with a pin through the calcaneus.

CASE 3. A white man, fifty-five years old, was admitted to Duke Hospital after a fall in which he sustained a severe trimalleolar fracture-dislocation of the ankle with lateral displacement of the talus. After failure to obtain reduction with a single manipulation, open reduction was carried out, and a large reflected portion of the torn deltoid ligament was found within the medial aspect of the mortise space which prevented reduction. Eight months after the removal of the cast, examination revealed satisfactory gait with little or no pain. There was some residual restriction of motion estimated at 10 to 20 per cent.

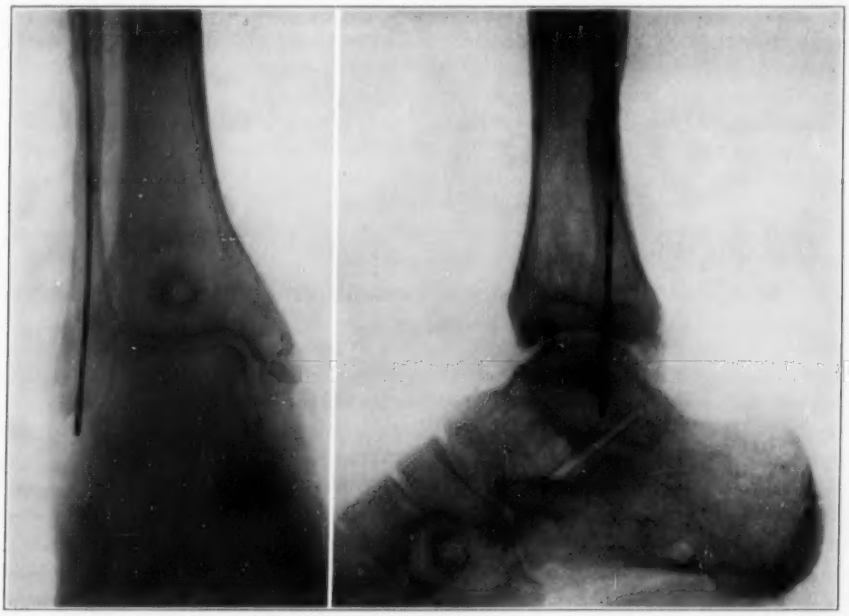

FIG. 4-C

At operation, the avulsed portion of the deltoid ligament was removed from the medial aspect of the joint space. Roentgenograms show mortise alignment after the removal of the screw from the medial malleolus sixteen months after injury.

CASE 4. A colored boy, nineteen years old, was admitted to Duke Hospital, with a severe trimalleolar fracture of the ankle which had been untreated for four days after injury. Manipulation on admission and again after six days of skeletal traction with a pin through the calcaneus failed to achieve any reduction of the laterally displaced talus. At operation a large portion of avulsed deltoid ligament was found within the medial aspect of the joint space. Upon the removal and repair of the avulsed portion of the ligament, reduction of the fracture and restoration of the normal mortise alignment was achieved with ease. The medial malleolar fragment was fixed with a metal screw, and the comminuted fibular fragments were fixed with intramedullary Kirschner wires.

This patient was, at the same time, under treatment for a compound comminuted fracture of the femur in the same extremity, and he was immobilized in a plaster spica for thirteen months. At examination three months after ambulation had been allowed, there was satisfactory unsupported gait, minimal limp, and pain which was experienced when the patient walked on uneven ground. There was 20 per cent. restriction of dorsiflexion and plantar flexion at the ankle.

SUMMARY

Two cases of trapping of the posterior tibial tendon, in one of which there was associated trapping of the posterior tibial nerve, and two cases with interposition of a reflected portion of the deltoid ligament within the medial aspect of the joint space, are presented as complications of severe fracture-dislocation of the ankle joint, requiring open reduction. Failure to achieve anatomical reduction in fractures about the ankle is probably the largest cause of poor end results. It is suggested that any patient with fracture-dislocation of the ankle[1] in which there is severe medial ligamentous injury and disruption of the mortise, which cannot be reduced by initial closed manipulation, be considered a candidate for early open surgical reduction. True anteroposterior roentgenograms of the ankle joint are necessary for any critical evaluation of mortise alignment.

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PLANOGRAPHIC DIAGNOSIS OF OSTEOMYELITIC SEQUESTRA *

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An osteomyelitic infection of low-grade virulence, but of long standing, is frequently associated with a sequestrum and is only controlled by removal of the sequestrum. A therapeutically unmodified course of events would occasionally result in the expulsion of the sequestrum through the persistently draining sinus tract. The course may be considerably accelerated by surgical removal of this untolerated fragment. Most sequestra can be identified by regular two-dimensional roentgenographic technique; others can be identified by sinography, three-dimensional roentgenography, and other specialized techniques. One of these additional techniques, planography, has been utilized by the authors in the Long Beach Veterans Administration Hospital to demonstrate previously unvisualized sequestra in cases of recurrent and chronic osteomyelitis.

* Read at the Annual Meeting of the Western Orthopedic Association, Sun Valley, Idaho, October 7, 1953.

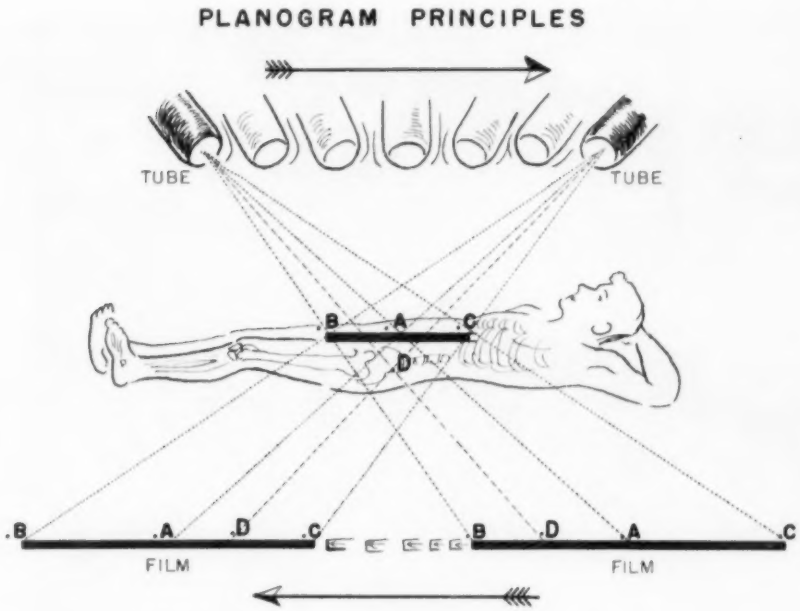

FIG. 1

Fig. 1: As indicated on the diagram, the tube and film move at a constant rate in opposite directions throughout an exposure of four seconds. Fifty milliamperes is used and the kilovolts vary, depending on the thickness of the part to be x-rayed. Points *A*, *B*, and *C* are always projected to the same position on the film. Arbitrary point *D* illustrates why other levels are not in focus and are blurred out. (Distances on this diagram are not drawn to scale.)

Planography has already been used in the diagnosis and recognition of affections of the skeletal system, although reports on this technique have been largely confined to the foreign literature. The planographic method has enjoyed a broad application, ranging from the demonstration of previously unrecognized fractures to the demonstration of obscure foreign bodies and localized bone abscesses. A review of the recent literature, both foreign and domestic, has not revealed sufficient evidence to allow for satisfactory evaluation of this technique in the demonstration of osteomyelitic sequestra.

In a series of twenty-two cases of chronic osteomyelitis, no evidence of sequestra could be demonstrated by regular roentgenographic techniques. In nine of these cases, sequestra were demonstrated by planography, and the findings were corroborated at surgery. Among these was one patient who had been operated upon several times unsuccessfully, and in whom the causative sequestrum was finally demonstrated by planography to be at a considerable distance from the previous sites of surgery.

The mathematical proof and theoretical considerations involved in the production of planograms have been adequately covered in excellent articles by Andrews, Twining, and others. Our own machine is a home-made, water-driven device, designed to move the tube stand of a conventional 100-milliampere table-top machine. The tube and film tray are connected by a steel rod with roller bearings to allow movement of the tube head and film in a straight line rather than in an arc, so that the roentgenogram produced is of a plane section of the body rather than a small sphere. The film and tube move in opposite directions during the exposure, the tube head rotating in such a fashion that its central ray constantly strikes the center of the film. As indicated on the diagram (Fig. 1), parts above and below the desired level will not be constantly in focus on the film during the exposure. The level of the parts to be examined can be predetermined by adjusting

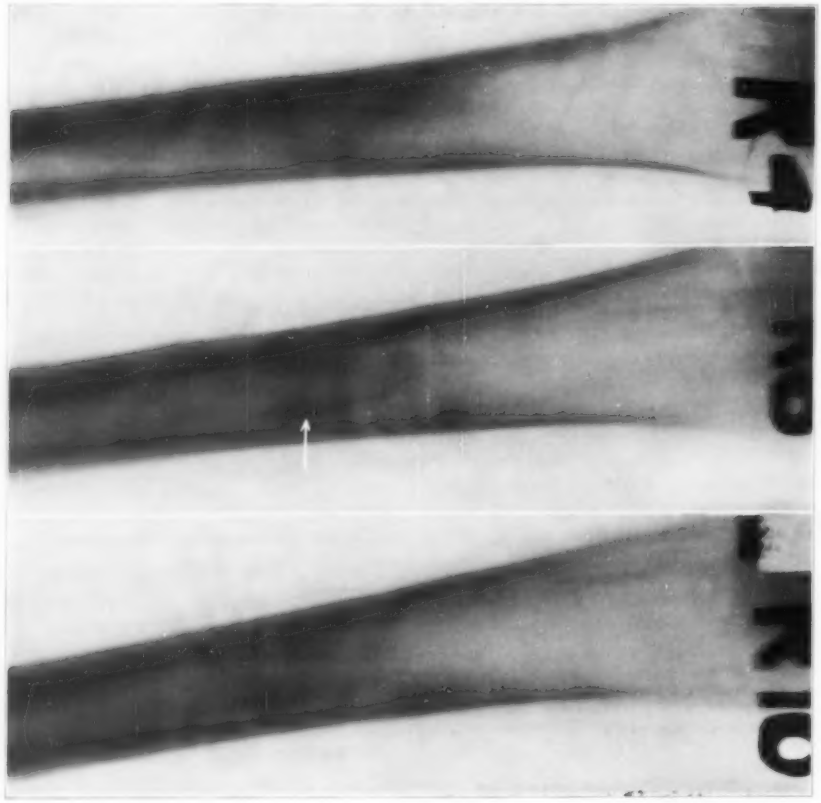

FIG. 2-B

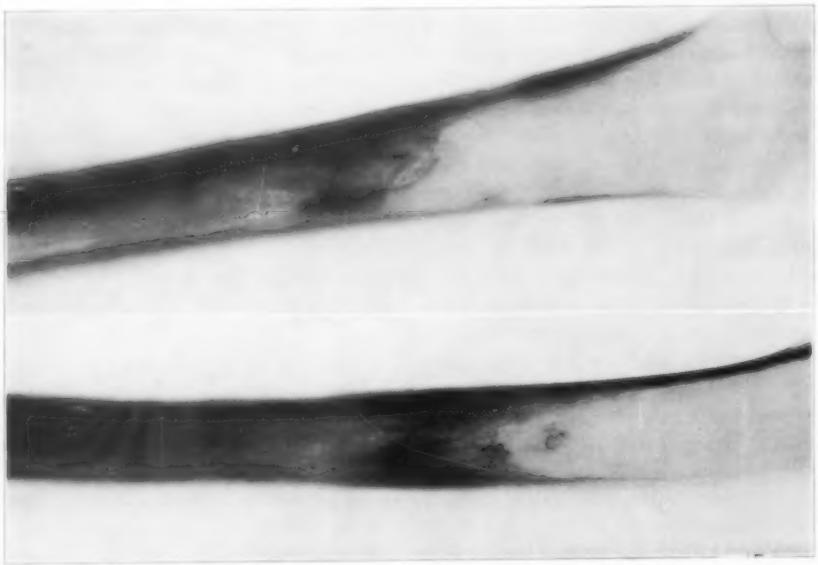

FIG. 2-A

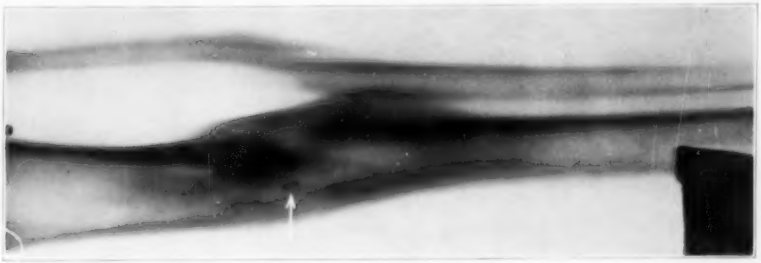

FIG. 4-B

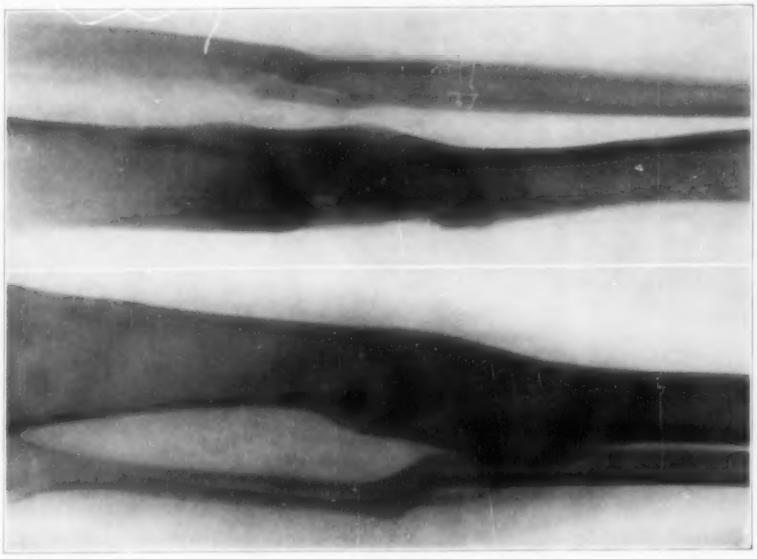

FIG. 4-A

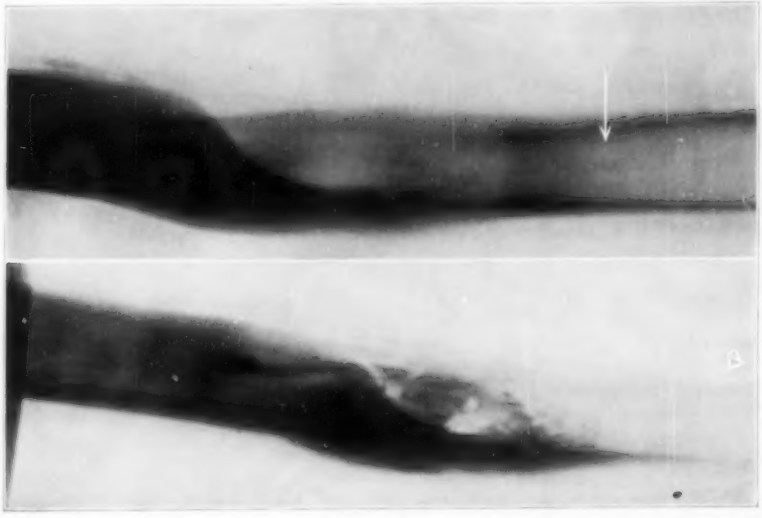

FIG. 3-B

FIG. 3-A

FIG. 5-A

FIG. 5-B

a fulcrum support to the steel rod holding the tube head and film. The closer the fulcrum is to the film, the deeper the body section obtained. Body-section roentgenography (planography) thereby enables the observer to study any selected area within the body without having to contend with the obscuring effect of overlying or underlying structures.

CASE REPORTS

CASE 1: The first case is that of a white male, twenty-six years old, with chronic osteomyelitis of the right femur. Roentgenograms made according to regular roentgenographic technique (Fig. 2-A) revealed several densities over the lower mid-shaft of the femur in both anteroposterior and lateral projections. It was not possible, however, to differentiate by means of regular technique between the superficial cortical thickening or exostoses, and more centrally located areas of sclerotic bone. In Figure 2-B, the planographic projections of the femoral shaft on the left and on the right reveal, respectively, the anterior and posterior surfaces of the femur, while the middle projection reveals a planographic section of the central portion of the shaft, disclosing a centrally located enostosis (indicated by the pointer). The enostosis was confirmed surgically.

CASE 2: This is the patient referred to earlier as one in whom several previous operations had been unsuccessful in relieving chronic osteomyelitis. The previous procedures had all been undertaken at the site of an old compound fracture and consisted in general débridement and curettage. Regular two-dimensional roentgenograms revealed the old fracture site and a surrounding area of sclerotic bone, but they failed to demonstrate any evidence of sequestration (Fig. 3-A). A lateral planogram (Fig. 3-B) revealed an area of translucency in the central portion of the shaft distal to the fracture site, and within this area of translucency was visualized an area of increased density. A sinus tract was found to traverse the medullary canal between this sequestrum and the old fracture site.

CASE 3: Figure 4-A shows the regular projection and Figure 4-B the planogram of the tibia of a man, twenty-nine years old, with chronic osteomyelitis. The suggested presence of a sequestrum at the old frac-

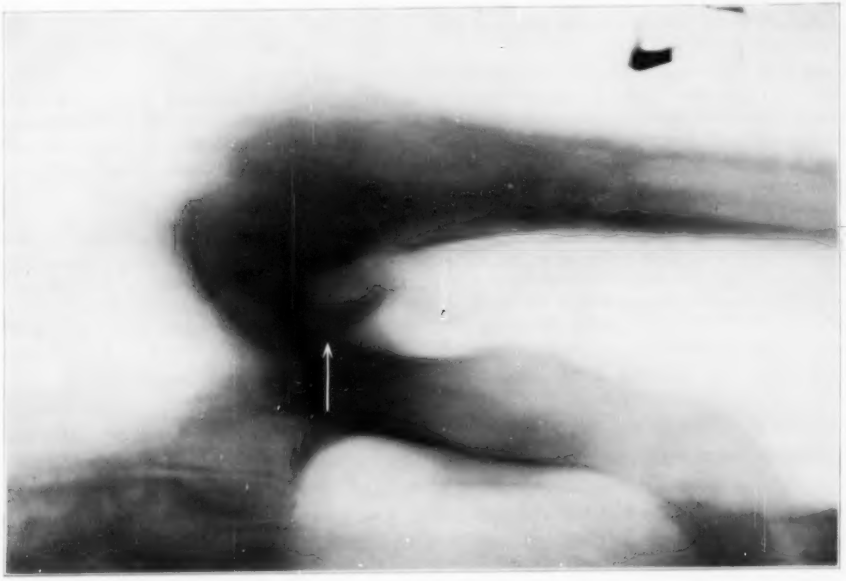

Fig. 6-B

Fig. 6-A

ture site was demonstrated more clearly in the planogram, where it was shown to be surrounded by an area of radiolucency which proved to be an abscess cavity.

CASE 4: In Figure 5-A are shown the anteroposterior and lateral projections of the femur of a white male, fifty-five years old, with hematogenous osteomyelitis of thirty-five years' duration. A previous extensive curettage in this area had been followed by packing with bone chips, and the patient remained asymptomatic for several years until recurrent severe inflammation and swelling of the thigh in this area necessitated rehospitalization. A positive differentiation between the partially re-organized bone-graft chips and the true sequestrum was obtained by planography (Fig. 5-B).

CASE 5: The final case is that of a forty-six-year-old white male with syphilis affecting the central nervous system and Charcot's disease of the left hip. An extensive chronically draining sinus of the left thigh developed and was excised several times with subsequent recurrence. Sinograms failed to reveal any communication between the capsule of the hip joint and the extensive subfascial abscess of the thigh (Fig. 6-A). An anteroposterior planogram of the hip (Fig. 6-B) revealed a large sequestrum consisting of the subarticular cortex of the femoral head.

DISCUSSION

Obviously there is much to be desired in the realm of clarity of image with present planographic technique. Much of this blurring is inherent in the technique itself. It should be emphasized that planography is not a substitute for good roentgenographic technique. High-quality routine roentgenograms and careful scrutiny of bony detail will eliminate the necessity of planography in the majority of cases. The chief criteria for recognition of sequestra by the planographic technique are (1) the demonstration of an area of density with a surrounding area of translucency, and (2) persistence of this halo effect through a sufficient series of successive planograms to exclude the possibility of a bone peninsula.

We do not consider the use of planograms a routine procedure in the diagnosis of osteomyelitic sequestra. Planography has, however, demonstrated itself to be a valuable diagnostic adjunct in recurrent cases of osteomyelitis in which operation has been unsuccessful; it has facilitated the planning of the operative procedure by demonstrating not infrequently an unsuspected sequestrum at some distance from the site of previous operation.

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ATRAUMATIC TREATMENT OF CONGENITAL DISLOCATION OF THE HIP JOINT

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Congenital dislocation of the hip joint still presents many unsolved problems. There is no generally acceptable theory to explain the origin of this wide-spread ailment, its curious sex linkage, its geographical distribution, or its hereditary characteristics. The remarkable papers of Duraiswami[1,2] may pave the way for a better understanding of the problem.

As clinicians, our chief concern is the question of a reliable and standardized treatment.

The purpose of this paper is to present a method of treatment which, while not entirely original, is the result of nearly twenty years of experience[4]. Soon after the establishment of the Orthopaedic Department at Haifa, it became clear that congenital dislocation of the hip joint is quite frequent in Israel, and that orthodox methods of treatment are not suitable—first, because of the subtropical climate and, second, because of lack of hospitalization facilities.

TABLE I

AGE AT BEGINNING OF TREATMENT IN 115 CASES

	0 to 5 months	6 to 12 months	1 to 2 years	Over 2 years
Number of Patients	40	37	32	6

In accordance with the teachings of Putti[5,6], our first concern was to ensure early diagnosis and treatment. Obviously, early treatment is a question of organization, which involves thorough training of pediatricians and general practitioners on the one hand and the education of mothers and nurses on the other. In our country, with its highly developed Public Health Service, we were able to enlist the collaboration of our colleagues and to make parents and nurses of the *crèches* "luxation conscious". The success of these efforts is best illustrated by Table I, which shows that by the end of the first year two-thirds, and by the end of the second year nine-tenths of the affected children had been brought under treatment.

Unfortunately, early treatment alone does not guarantee uniformly good results. It is questionable if the accepted method of immobilization for many months after forced reduction of the femoral head is the best treatment. Growing experience has shown that, if treatment is instituted as early as possible and if it is done simply by bringing the femoral head in apposition to the acetabulum, a fairly large percentage of good results can be predicted.

In 1937 we began to abandon the original Lorenz plaster method step by step. At first we used Putti's appliance, but we soon discarded this because it proved bulky and heavy, and rapidly became soiled. Frejka's cushion was light, but it proved hot and difficult to keep clean. Finally, we adopted a modification of Hilgenreiner's splint (Fig. 1) which is light, easily adaptable, reasonably easy to keep clean, and entirely safe. The main difference from the original design is the addition of a pair of leather cuffs loosely attached to the side extensions by narrow leather straps (Fig. 2).

A description of our method as it has been standardized follows.

FIG. 1

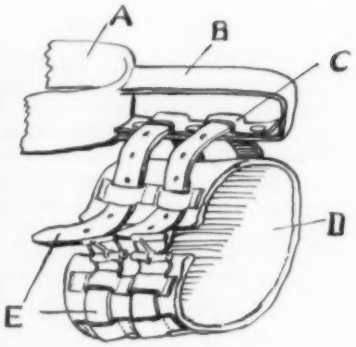

FIG. 2

Fig. 1: Showing the modified Hilgenreiner splint with adjustable cuffs.

Fig. 2: Details of the adjustable cuff and its attachments: *A:* padded belt; *B:* side extension; *C:* leather strip riveted to side extension; *D:* cuff; *E:* loose leather straps with attachments.

1. *Uncomplicated Cases*

The splint is usually applied during the second or third quarter of the first year of life. The cuffs are fastened around the thighs without undue tension by means of the straps and buckles previously described.

The parents are advised to elevate the head of the baby's bed by means of wooden blocks or two bricks to a height of approximately twenty centimeters. The mattress is replaced by a piece of plywood covered by a sheet. In order to prevent the child from sliding down to the foot of the bed, the side extensions of the splint are fastened to the bed by a piece of string or the like. In this position, the patient's body does not become soiled with urine, for this runs down into the diapers. Moreover, the baby is easily handled, being fed, cleaned, or nursed either on his stomach or on his back.

Every five or six days the baby is brought in for a check-up and the straps are tightened as the adductor contracture is overcome. Gradually the hips are brought into full abduction; as a rule, this takes two or three weeks. The point of resistance of the soft tissues is never exceeded when the cuffs are adjusted to a new position. After complete abduction to the classical "frog-leg" position has been attained, the splint is left on for another few days. Between the third and fourth weeks the mother is allowed to remove the appliance for bathing but must always reapply it immediately. After two or three weeks more, the splint is taken off for one hour in the forenoon and one hour in the afternoon. If the monthly roentgenographic examination shows satisfactory progress, an additional hour of freedom is granted both in the morning and in the afternoon. These periods are gradually increased until, after three or four months, the splint is worn only when the child is asleep. It is used thereafter as a night splint for an average period of nine months, sometimes for as long as two years.

While the child is in the splint, his spontaneous movements are not restrained. On the contrary, the babies are entirely free to sit up, to crawl, or even to stand. We feel that the early movements of the hip, especially rotation, are of value and prevent later complications. Reluxation is very unusual in infants and, if it does occur, it is usually found to be the result of poor attendance or of erroneous interpretation of the roentgenograms.

By the time the splint is discontinued, the hips are perfectly movable, and no after-treatment with massage, manipulation, or exercises is ever required. Walking is begun during the part-time splinting period and is accomplished without undue difficulty. Roentgenograms are made at first every three months and then at increasing intervals until they are made once a year. Yearly x-rays are then procured until puberty.

CASE 1. A girl, two years of age when first seen, was walking with a severe bilateral limp. Hilgenreiner's splint was applied, full abduction of the hips being achieved in three weeks. The splint was removed after six weeks and discarded after five months. After six years, the right femoral head was in perfect position and had normal shape; the left head, slightly smaller than the right, was in good position also. Functionally both hips were excellent.

This case shows that, even in older children, there is a fair chance of success by gradual reduction. Therefore, a trial is worth while before reposition under anaesthesia is undertaken.

FIG. 3-A
Photograph of the adjustable V splint.

FIG. 3-B
Front view of the V splint attached.

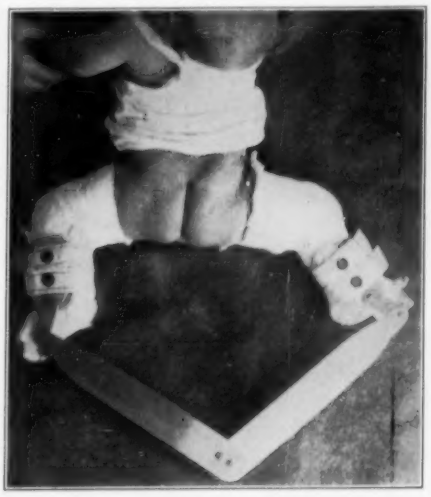

FIG. 3-C
Posterior view of the V splint attached.

2. *"Stubborn" Cases*

A case is called "stubborn" if in the course of about three weeks it becomes evident that the adduction contracture cannot be overcome with the standard splint. In these cases we still do not use any type of force but again rely on gradual stretching of the tight structures. After many trials, a method was developed which seemed quite satisfactory, combining efficiency with simplicity. It employs a V splint, a modification of a splint proposed by Plato Schwartz, which may be adjusted to any position desired.

As shown in Figures 3-A, 3-B, and 3-C, the splint resembles a caliper made of stain-

less steel. To the ends of each arm of the caliper, movable pads are attached. These pads are fastened by straps and buckles to plaster casts previously applied to each of the child's limbs. At the hinge of the caliper there are a number of holes arranged in a semicircle in the uppermost arm of the splint. Into one of these holes is fitted a small bolt which protrudes from the surface of the second arm underneath. By loosening the wing nut on the central screw and shifting the bolt to the appropriate hole, one may obtain any required angle of opening without removing the splint from the patient's body.

Our procedure in stubborn cases is now as follows: Toe-to-groin plaster casts are applied to each limb, the feet and knees being held at right angles. The extremities are brought to the maximal degree of abduction which can be obtained *without force* and are attached to the V splint. Occasionally, if it is felt that the parents are not reliable, the upper pads are incorporated into the plaster itself, but in the vast majority of cases the splint is simply fastened by its straps and buckles. The mothers are advised to keep the children recumbent during the first few days and to place a small hard cushion under the apex of the splint to avoid painful strain on the hips from the weight of the sagging appliance. Every five or six days abduction is increased by opening up the splint by one or two holes until the frog-leg position is reached. The V splint has then served its purpose and the next step must be considered. Usually treatment is continued with Hilgenreiner's splint. If the acetabulum is extremely shallow, the plaster cast is left in place, and a Ponseti bar is added. Rotatory movements are possible from the beginning and the children usually sit up after a few days.

Case 2. A girl, who was first seen at eighteen months of age, was walking with a severe limp and had no abduction of either hip joint (Fig. 4-A). A V splint was applied. Full abduction was achieved in three weeks. Treatment was then continued with Hilgenreiner's splint, which was gradually removed after six weeks and discarded after six months. A Denis Browne splint was used as a night splint for another five months. The result after four years is shown in Figure 4-B. The roentgenographic appearance of the hips is very nearly normal, and functionally both hips are excellent.

Case 3. A girl, sixteen months of age, was walking with a severe limp on both sides when treatment was started (Fig. 5-A). A V splint was applied for six weeks. Full abduction was achieved in four weeks. Hilgenreiner's splint was used for seven months and was removed after four weeks for gradually increasing periods. The result after four years is shown in Figure 5-B. On both sides the dislocation has been reduced. The left hip is almost normal, but the right hip shows signs of aseptic necrosis, and the roof of the acetabulum is still oblique. Function in both hips has remained good to the present.

Occasionally the hips are still dislocated after full abduction has been obtained. In this event, gentle manipulation by rotatory movements, together with gentle forward pressure on the posterior aspect of the greater trochanter, usually will effect reduction. One can feel the dislocated head slip into the acetabulum smoothly, because all the soft parts have been stretched and there is no tension. The loud thud which once gladdened the ears of the orthopaedic surgeon is not heard. Even anaesthesia is not always required because so little force is used. Treatment is then continued as previously described.

Case 4. A girl, three years of age, with a severe limp on the left side and shortening of the left extremity amounting to 3.5 centimeters, was treated with a V splint. After two and a half months, the femoral head was still outside the acetabulum. Under general anaesthesia reduction was carried out fairly easily. A plaster cast immobilizing the hips in the Lorenz position was worn for three weeks. This was followed by Hilgenreiner's splint, which after seven weeks was removed for gradually increasing periods. The abduction contracture slowly subsided, and the splint was discarded entirely after seven months. After three years the left femoral head lay in the acetabulum, but its bony architecture was loose, and the acetabular roof was slanting. After four years, the left limb showed shortening of one centimeter. The hip was freely movable, and the Trendelenburg sign was negative. A slight limp was apparent when the patient was fatigued.

Sometimes the continued use of Hilgenreiner's splint meets with difficulties, especially in older children who resist it. In this event, the Denis Browne appliance is used. At first,

FIG. 4-A

Case 2, a girl, eighteen months old. Roentgenogram made before treatment.

FIG. 4-B

Roentgenogram made four years later.

the simple metal arch which is fixed to the shoes was used. It soon became apparent, however, that this model puts a rather severe strain upon the medial collateral ligaments of the knee joint. Therefore, a more cumbersome model has been used with side bars, belts, and kneecaps. This has been tolerated much better.

FIG. 5-A

Case 3, a girl, sixteen months old. Roentgenogram made before treatment.

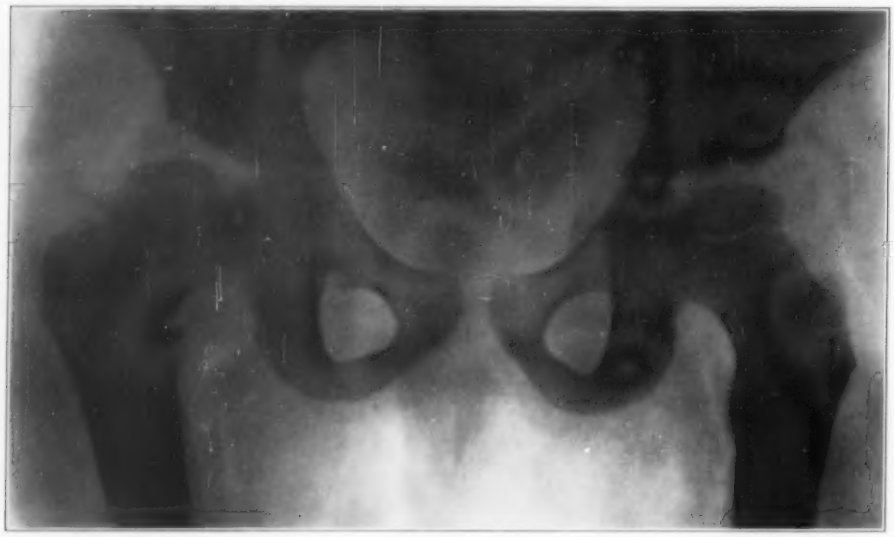

FIG. 5-B

Roentgenogram made four years later.

3. *Complicated Cases*

A case is considered to be complicated if the femoral head cannot be placed in the acetabulum by any of the procedures described. This almost never occurs in very young infants, but is found with increasing frequency in the older age groups. Among our records we found only five cases of absolutely irreducible dislocation. Four of these were in patients over two years of age. One of these was a mentally retarded child with multiple congenital malformations and another had a grotesque malformation of the entire proximal end of the femur.

Forceful manipulation and reduction by "boring the acetabulum" or by "ramming

TABLE II

TREATMENT BY REDUCTION UNDER ANAESTHESIA: 25 CASES

Result	Age at Beginning of Treatment			
	0 to 5 months (*No. of Patients*)	6 to 12 months (*No. of Patients*)	1 to 2 years (*No. of Patients*)	Over 2 years (*No. of Patients*)
Good	0	0	3	0
Fair	0	4	9	1
Poor	0	3	0	3
Failure	0	0	1	1

down the head" (quoted from recent papers) is never attempted. No type of mechanical apparatus is considered of value, simply because we are convinced that an already defective joint will be damaged and nothing will be gained by such methods. By abduction alone the femoral head can be brought down with less discomfort to the patient and as safely as by methods employing traction and extension. This method should be attempted as a measure preceding manipulative reduction under general anaesthesia or open reduction.

TABLE III

TREATMENT BY PLASTER AND SPLINT (INCLUDING V SPLINT): 29 CASES

Result	Age at Beginning of Treatment			
	0 to 5 months (*No. of Patients*)	6 to 12 months (*No. of Patients*)	1 to 2 years (*No. of Patients*)	Over 2 years (*No. of Patients*)
Good	2	1	4	0
Fair	1	7	9	1
Poor	0	2	1	0
Failure	0	0	0	1

RESULTS

Of a total of approximately 200 patients, only those were selected who had been kept under constant supervision for at least two years and had been re-examined during the last six months. This left 115 cases to be studied—seventy-seven bilateral and thirty-eight unilateral dislocations, a total of 192 hips. The relatively large number of hips treated by reposition under anaesthesia (Table II) represents those cases which came under our care before the present standard method had been adopted. These cases serve as controls with which to compare the results of our present method of treatment.

The grading of "good" indicates a perfect anatomical and functional result. In a "fair" result the patient had no complaint, but the roentgenogram showed evidence of anatomical imperfection, such as a plump, slightly eccentric head, a slight degree of coxa vara, or a slanting acetabular roof.

TABLE IV

TREATMENT BY SPLINT ONLY: 62 CASES

Result	Age at Beginning of Treatment			
	0 to 5 months (*No. of Patients*)	6 to 12 months (*No. of Patients*)	1 to 2 years (*No. of Patients*)	Over 2 years (*No. of Patients*)
Good	27	12	3	1
Fair	7	5	3	0
Poor	3	0	0	0
Failure	1	0	0	0

The result was rated "poor" if both anatomical and functional defects were present. The abnormalities already noted were present in this group, but they were of greater severity, and marked fatigability, pain, and limp were present. The cases classified as "failures" required operation because of a defective, unstable joint, reluxation, and progressive deformity of the head and neck.

Table II shows that the majority of the children treated by manipulation under anaesthesia belonged to the older age group, less than one third being under one year of age. Only three cases of the twenty-five could be graded as "good". About half of the total had some slight defect, while one third were rated "poor" or "failure". These results conform with those obtained in other clinics. They compare favorably with the general results obtained in patients over two years of age. The advantages of early treatment with the splint are obvious in Table IV. Of sixty-one patients, fifty-five were treated before the end of the first year of life. In about two thirds of all the cases the results were good, while in one fourth they were fair. So far, there has been only one failure—a hip which redislocated some time after reduction.

Table III shows the outcome of twenty-nine "stubborn" cases treated by plaster and splints. Ideal results were achieved in only seven of them. Roughly two thirds of these hips showed some anatomical defects, usually as the result of disintegration of the femoral head. Nevertheless, the functional results were such that they were graded as "fair". In three cases the result was poor and in one a failure resulted, necessitating operative treatment. It should be emphasized that, among the cases with a fair result, even in the group treated by splinting alone, some have shown transitory signs of aseptic necrosis of the femoral head which eventually healed, resulting in only minor anatomical changes in the shape, but not in the internal architecture of the femoral head.

It is of interest to note that during a period of several years some dozen children have been sent to the Orthopaedic Department because of suspected congenital dislocation of the hip. On examination, a more or less severe abduction limitation of the hip was found, but the roentgenogram failed to reveal a dislocation. The vast majority of these hips appeared perfectly normal, although there were some cases of delayed or asymmetrical development of the ossification centers. In order to avoid any treatment not strictly warranted, none of these children were put into splints initially, but they were kept under close supervision. Usually the contracture subsided spontaneously in the course of three or four months. The smaller femoral head sometimes took as long as two years to catch up with the normal side. In a few patients Putti's triad tended to develop and these were treated with splints. We are unable to explain these borderline cases, but wish merely to call attention to them. The follow-up in these cases is too short for final evaluation (probably twenty years or more are needed). However, we feel that treatment by early splinting, even in stubborn cases, is easier, less expensive, and at least as safe as the time-honored methods which are widely used.

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FRACTURE OF THE CARPAL NAVICULAR (SCAPHOID) BONE

Some Observations Based on Treatment by Open Reduction and Internal Fixation *

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Fracture of the carpal navicular (scaphoid) remains an essentially unsolved problem. Little is known about its early pathology, for inspection has seldom been possible until non-union or aseptic necrosis has necessitated a late operation. Theory and therapy have perforce been established almost solely upon a basis of anatomy and roentgenographic studies. The resultant accepted treatment has been immobilization in a snug circular plaster dressing from just below the elbow to the metacarpal necks until the fracture is soundly united or irreversibly ununited.

The practical disadvantages of this treatment are obvious and may be small or great, depending upon the duration of the immobilization and the patient's occupation. Reassurance that the majority of carpal navicular fractures unite, if immobilized adequately for a sufficiently long period, is small comfort to the breadwinner who cannot do his job in a plaster gauntlet. His main interest is to regain the normal usefulness of his hand as soon as possible, and he might well wish for a form of treatment which would maintain the apposition of the fragments and at the same time permit motion and use of the wrist throughout a healing period which is often prolonged. Toward this end, open reduction and internal fixation have been carried out in nineteen fractures of the carpal navicular over a nine-year period. This report is not intended as an advocacy of this method but rather as a commentary on some of the clinical observations, problems, complications, and results attendant upon this experience.

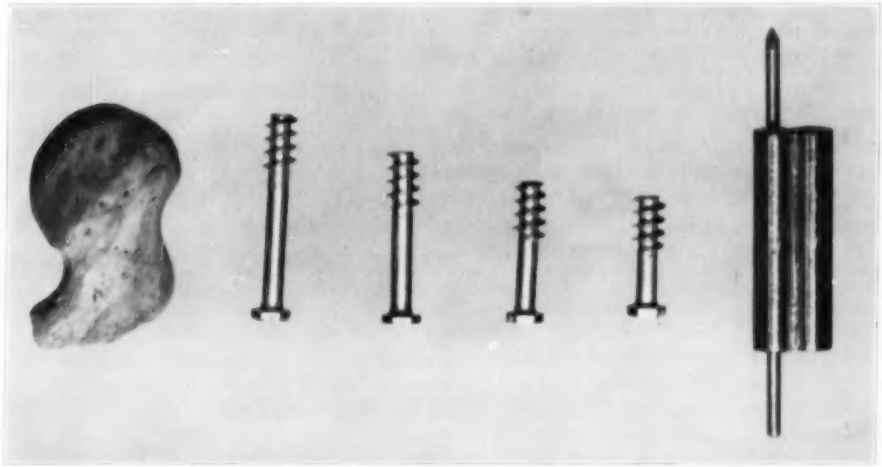

FIG. 1

Fig. 1: Carpal navicular bone beside Vitallium lag screws in lengths seven-eighths, six-eighths, five-eighths, and four-eighths inches with shank to fit size No. 42 drill. At the right is a double-tube guide for stabilizing fracture fragments and guiding drill point.

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 22, 1954.

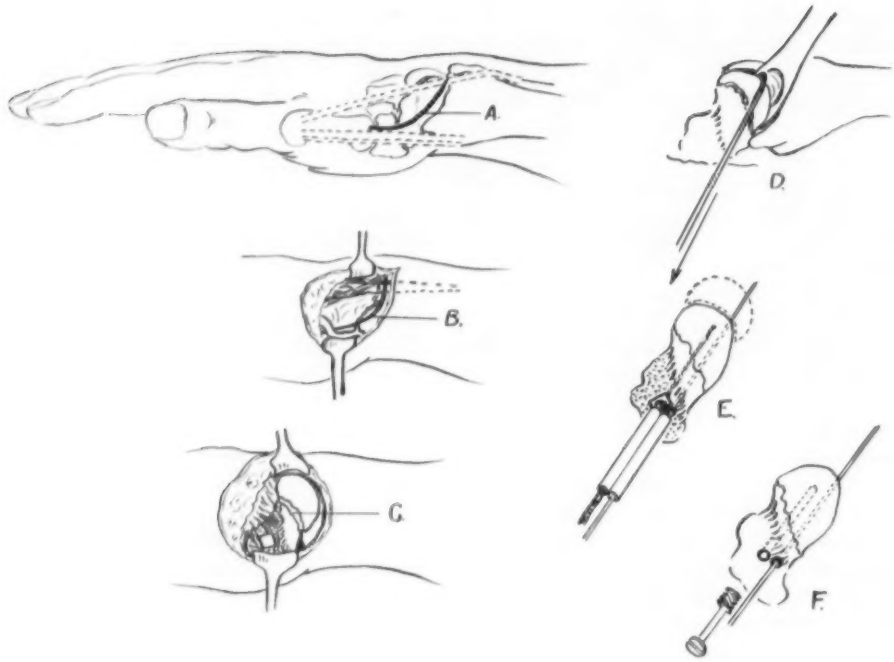

FIG. 2

Exposure and fixation of the carpal navicular.

A. Skin incision and its relationship to the structures in the anatomical snuff-box.

B. Incision of the joint capsule. The skin flaps are retracted, showing the position of the superficial radial nerves in the dorsal aspect of the exposure and the radial artery in the volar aspect. Both must be identified and protected from harm. The dorsal carpal branch of the radial artery should be divided and ligated at its point of intersection with the capsular incision.

C. Slight palmar flexion and strong ulnar deviation of the hand produce a good view of the carpal navicular when the capsule is retracted. The soft-part attachments distal to the dorsal ridge of the navicular (stippled) should not be elevated or disturbed, except over a small area (square) sufficient to allow insertion of a drill and screw.

D. When the fracture is unstable, the distal fragment is stabilized by controlling the hand and forearm. The proximal fragment usually can be controlled adequately by a skin hook inserted between it and the lunate. The use of small slightly spoon-shaped elevators between the proximal fragment and the radius or lunate is also of considerable help in stabilizing the slippery proximal fragment.

E. Maintenance of unstable fragments in perfect position usually proves impossible, except when they are transfixed by a stiff small Kirschner wire. Additional stability is derived from transfixion of the lunate as well. The double-tube guide is then placed over the projecting end of the wire and the screw hole is drilled as illustrated.

F. Drill and drill guide are removed and the lag screw is inserted. The caliber of the drill and the shank of the screw should be the same. Screw length is determined by shank length, which should be slightly greater than the distance between the point of entrance of the drill and the fracture line. The transfixion wire is removed following insertion of the screw.

SELECTION OF CASES

The following were considered acceptable indications for open reduction and internal fixation:

1. A justifiable reason for obviating the penalties of prolonged plaster immobilization;
2. A fracture with displacement or instability at any level;
3. A fracture without displacement through or proximal to the waist of the navicular;
4. A symptomatic ununited fracture without avascular necrosis or arthritis.

Arthritis could not always be identified or evaluated accurately by roentgenogram. Large spurs sometimes were found to be innocent or easily removable, while a normal-

appearing joint sometimes proved to be the seat of diffusely irritated small hypertrophic excrescences. An ununited fracture was explored only when, after a full discussion of all therapeutic possibilities (bone-grafting, excision of one or both fragments, internal fixation, and wrist fusion), the surgeon had been granted permission to proceed in accordance with the dictates of the pathological conditions encountered.

PROCEDURE

Exposure

Exposure of the navicular sufficient to permit visualization of the proximal and distal ends of the bone simultaneously, yet without undue surgical insult to its soft-part attachments, requires appropriate small tools and an exacting attention to certain small details of technique. A tourniquet should be used. The skin incision (Fig. 2, *A*) curves dorsalward across the anatomical snuff-box from the base of the thumb to the point where the extensor pollicis longus tendon enters its radial groove. The terminal sensory branches of the radial nerve and the main trunk of the radial artery must be identified and protected by gentle retraction. The dorsal-carpal branch of the radial artery traverses the line of incision of the joint capsule (Fig. 2, *B*), at which point it is ligated and divided. Traction, slight palmar flexion, and strong ulnar deviation of the hand by an assistant then bring the navicular into good view. A minimum of soft-tissue attachments should be elevated from the dorsolateral aspect of the tubercle of the navicular. If the navicular-multangular joint is first identified, the surgeon becomes sufficiently oriented so that he is required to bare only enough bone on the surface of the distal fragment to permit the insertion of a drill point.

Reduction and Fixation

In this series the fixation of stable fractures presented no problems. Perfect apposition of the fragments was maintained securely by intact articular cartilage or by common soft-part attachments. To drill a hole through the fragments, followed by the insertion of a Vitallium lag screw of appropriate length, proved to be a simple matter, somewhat comparable to the nailing of an impacted valgus fracture of the neck of the femur.

The difficulties in the reduction and fixation of unstable fractures, however, proved to be comparable to the problems encountered in the reduction and nailing of a grossly unstable vertical subcapital fracture of the neck of the femur. All navicular fractures with displacement, as well as some navicular fractures without apparent displacement, were unstable. It proved to be virtually impossible to align the small slippery proximal fragments and to maintain them in position without considerable contusion and laceration of their surfaces, except when both fragments were transfixed with a small stiff Kirschner wire (Fig. 2, *E*). Only after the fracture had been reduced and the fragments had been transfixed in this manner could a hole be drilled and a fixation screw inserted without undue insult to the bone and its soft-part connections (Fig. 2, *F*).

COMPLICATIONS

The radial artery was injured on two occasions. Once, the vessel was accidentally incised during exposure of the navicular; another time, it was lacerated by a needle during closure of the wound. Both instances represented technical faults by the surgeon and were not due to reduction and fixation of these fractures. Both arteries were ligated and divided in the distal extremity of the anatomical snuff-box, and in neither instance was any subsequent circulatory deficit demonstable in the hand.

The radial nerve was occasionally compressed by retraction sufficient to produce temporary hypo aesthesia (and in one instance a small spot of persistent relative hypoaesthesia) on the dorsum of the first interosseous space.

The lunate bone was intentionally pierced by the Kirschner wire, which was used in most unstable fractures to transfix the fragments, in an effort to enhance stability during

the insertion of drill and screw. No harmful sequellae were noted. In two instances, the screw inserted was too long, so that postoperatively the lunate was fixed to the reassembled navicular. Both screws were removed following union of the fractures. Neither patient had painful symptoms or restriction of motion.

Contiguous tendon sheaths became irritated by the heads of the fixation screws in two patients. In one, the screw was inserted through the volar aspect of the tubercle of the navicular, and the flexor carpi radialis mechanism was involved; in another, the thumb tendons were mechanically irritated in the distal extremity of the anatomical snuff-box. Removal of both screws following union of the fractures produced rapid and complete subsidence of symptoms.

OPERATIVE FINDINGS

Viability of the Fragments

Stable or undisplaced fragments were not mobilized for inspection. In other fractures, the broken end of the proximal fragment was observed not to bleed freely in any case. It is not to be construed that all such fragments were considered to be avascular, since it was deemed inadvisable to explore the underlying bone. The broken surfaces of the distal fragments were observed to bleed in cases explored soon after injury.

In early fractures with any displacement, the wrist joint was filled with old, unclotted blood; in those without displacement, the joint was under tension due to effusion containing little or no blood. In all early fractures, the soft parts attaching to the distal fragment were bruised, ecchymotic, and markedly oedematous. In displaced and unstable fractures, there was rarely any appreciable preservation of soft-tissue attachments to the proximal fragment.

FIG. 3-A

Stability

The stability of a carpal navicular fracture could not be measured by its roentgenographic appearance. Any displacement of the

FIG. 3-B

FIG. 3-C

Fig. 3-A: The penalty of an attempt to internally fix an unstable fracture without first transfixing the reduced fragments with a small stiff steel pin.

Fig. 3-B: Postoperative roentgenogram. Note the level of the fracture.

Fig. 3-C: Four years after operation, showing bony union and an excellent result. The patient had returned to her job as kitchen helper two weeks after operation.

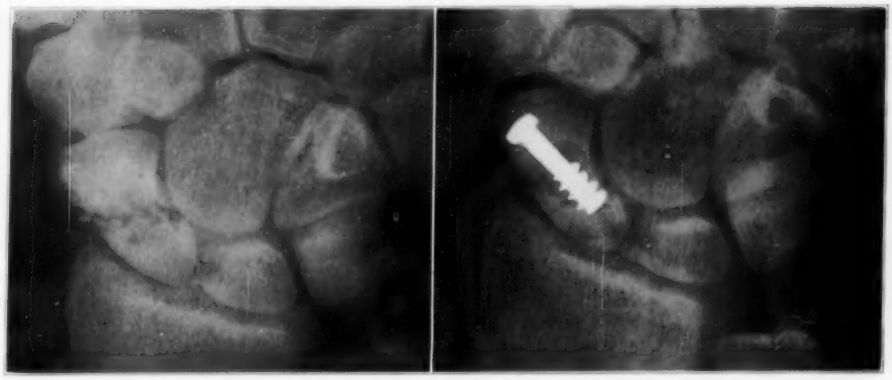

FIG. 4-A

FIG. 4-B

Fig. 4-A: December 1951. Roentgenogram shows non-union with cavitation of thirteen months' duration.

Fig. 4-B: July 1952. Six months after fixation. Cavitation seems to be regressing.

Fig. 4-C: December 1953. Two years after fixation. Cavitation is filled in, but there is no bony union. The patient had resumed full work as a machinist three weeks after operation.

FIG. 4-C

fragments was pathognomonic of gross instability, but absence of displacement was not always synonymous with stability. As a general rule, the presence and amount of stability increased or decreased in direct proportion to the size of the distal bone fragment.

Stable fractures through or proximal to the waist of the navicular were characterized by intact or incompletely fractured articular cartilage. As a result, no shearing or rotatory motion occurred between the fragments, even on motion of the wrist. In fractures of this type, it appeared likely that union might well occur regardless of the type, or the presence or absence of treatment, provided that the part was protected against further injury during the healing period. In others, a small remaining connection of intact cartilage acted as a hinge which, although it held the fragments in contact, also allowed the contralateral side of the fracture to open and close with certain wrist motions. So long as some intact cartilaginous or soft-tissue connections remained, most fractures seemed quite stable.

Unstable fractures were characterized by a complete disruption of the articular cartilage. It was not possible to obtain and maintain complete anatomical reduction of the fragments by any manipulation or posture of the wrist and hand. The slightest motion of the wrist or of the thumb resulted in some small shearing or rotatory motion of one fragment on the other. Even with the wrist and the thumb held immobile, gentle compression of the carpus against the radius, such as would repeatedly occur from muscle forces (even within the best of plaster dressings), resulted in some change in the position of the fragments. It was quite apparent that no form of external fixation could really immobilize an unstable navicular fracture, and it was equally clear that no single position of the hand would consistently maintain the reduction of the displaced fragments. It was difficult to comprehend how any such unstable fracture could ever heal by bony union when treated by plaster dressings, since each small motion of the thumb and each small com-

pression force not only moved the fragments on each other but also washed joint fluid through the fracture gap.

The implications of these observations are pertinent to treatment of the lesion by a plaster dressing. It is argued, on the one hand, that efficient external immobilization must extend to the interphalangeal joint of the thumb and, on the other, that the plaster dressing should end at the metacarpophalangeal joint. The former efficiently obliterates, and the latter preserves, the function of the hand. Operative findings indicate that, when the fracture is stable, secure fixation and apposition of the fracture fragments will be maintained by either dressing; when the fracture is unstable, neither provides complete fixation. The theoretical advantages of immobilizing the proximal phalanx of the thumb are invalid; the penalties are practical and serious. The thumb should be opposed to the index finger, and its joints should be left free to move.

Cavitation at the Fracture Site

Delay in, or interference with, the healing process is often signaled by a change in the roentgenographic appearance of the fracture, from a linear crack to what seems to be a decalcified cyst (Fig. 4-A). Watson-Jones attributes this to hyperaemic de ossification. Operative findings failed to substantiate this concept and added little to comprehension of the significance of such phenomena. There are few surrounding soft tissues to play host to a hyperaemia. The proximal fragment is hypo-aemic rather than hyperaemic, yet cavitation occurs coincidentally in both fragments. The process is not one of decalcification alone but of actual cyst formation, characterized by a loss of bone matrix as well as of mineral substance.

FIG. 5-A

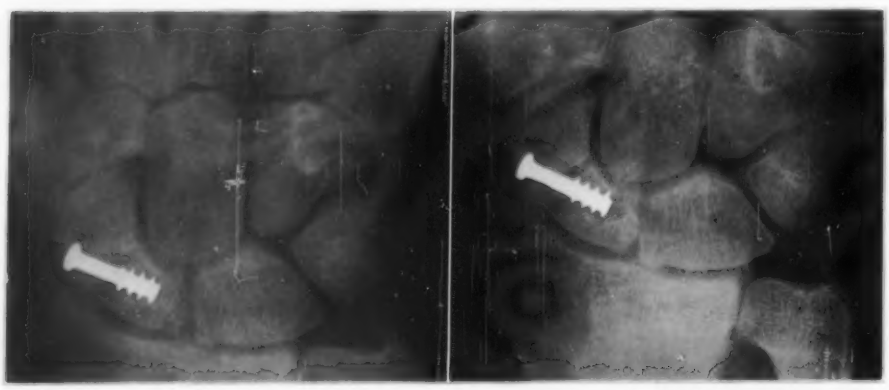

FIG. 5-B FIG. 5-C

Fig. 5-A: 1949. Roentgenogram shows non-union with sclerosis of nine months' duration. Radial spur and excess bone on distal fragment were removed coincidentally with fixation of fracture. Fracture surfaces were not freshened.

Fig. 5-B: 1950. Six months after operation, roentgenogram shows less sclerosis and possible beginning union.

Fig. 5-C: 1952. There was still no union, but less sclerosis, and the patient had no symptoms. He had regained full use of the hand and had been driving a large bus in city traffic since twenty-six days after operation.

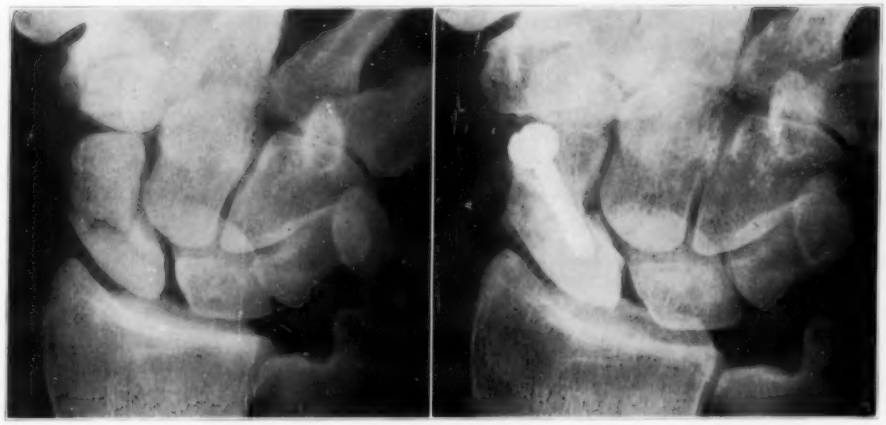

FIG. 6-A FIG. 6-B

FIG. 6-C FIG. 6-D

Fig. 6-A: Early roentgenogram of an unstable fracture, 1945.

Fig. 6-B: Avascular necrosis of proximal fragments had reached a peak about six months after operation.

Fig. 6-C: Proximal fragment shows revascularization which was not complete until 1948.

Fig. 6-D: Roentgenogram shows bony union and no residual avascular necrosis following removal of the screw, 1949. The patient had returned to full work as a porter handling freight in a railway express office one week after operation.

Possibly mineral components migrate from the bone ends as in all fractures, but in increased amounts, since they are washed away by joint fluid. Why the collagenous matrix of the bone should also disintegrate and disappear in the presence of joint fluid, as occurs in other intra-articular fractures and certain arthridites, is not clear, but it has been seen that the process is reversible. Repair may obliterate the cyst by the ingrowth of granulation tissue from its walls, and these tissues may eventually coalesce, ossify, and result in bony union. Clinical experiences indicate that consummation of such a reaction not only is uncertain, but also that several months to a year will be required before it occurs.

Non-Union

The term "non-union" was literally correct with respect to the unhealed fractures examined. No fibrous union was found between the bone ends. The fracture surfaces were polished smooth and covered by glistening fibrocartilage. Joint fluid lubricated the interval between the fragments as freely as in the adjacent true articulation. Periarticular

TABLE I

LATE INTERNAL FIXATION OF UNUNITED FRACTURES OF THE CARPAL NAVICULAR

Period Disabled for Work before Operation	Time Work Resumed after Operation and Occupation	Result Rated A — S — E* and Period after Operation	Residual Defect	Bony Union (As shown by x-ray)
2 months (Sclerosis at fracture)	11 days, elevator operator.	4 — 3 — 4† at 21 mos.	Tender at screw head.	None
9 months	26 days, bus driver.	4 — 3 — 4 at 18 mos.	Limitation of 15° of extension.	None (Fig. 5-C)
24 months	7 days, bartender.	4 — 3 — 4 at 48 mos.	Occasional discomfort.	Uncertain, probably not.
13 months	21 days, machinist.	4 — 3 — 4 at 24 mos.	Slightly weak.	None (Fig. 4-C)
4 months (With large cyst)	7 weeks (wearing gauntlet), at school.	4 — 3 — 4 at 6 mos.	Marked extension defect of wrist.	Regression of cyst, progression of necrosis at 6 mos.

* A: Anatomical result.
S: Symptoms and function.
E: Economic recovery.

† 4 = 100 per cent.
3 = 75 to 99 per cent.
2 = 50 to 74 per cent.
1 = 25 to 49 per cent.
0 = less than 25 per cent.

fibrosis and fibrous adhesions from the periphery of the fracture to the joint capsule reduced the mobility of each fragment somewhat, but all such lesions remained unstable and were characterized by some hypermobility of the fragments. Those subjected to internal fixation (Table I) were free from avascular necrosis and arthritis. The rapidity

TABLE II

RESULTS IN EARLY INTERNAL FIXATION OF FRACTURES WITHOUT DISPLACEMENT (STABLE)

Time Work Resumed after Operation and Occupation	Result Rated A — S — E* and Period after Operation	Residual Defect	Bony Union (As shown by x-ray)
16 days, athletics.	4 — 4 — 4† at 48 mos.	Screw removed.**	Yes
7 days, housewife.	4 — 3 — 4 at 36 mos.	Limitation of 30° of flexion.	Yes
14 days, office work.	4 — 3 — 4 at 60 mos.	Discomfort during bad weather.	Yes
10 days, ordinary activities; 30 days, played basketball.	4 — 4 — 4 at 60 mos.	Screw removed.**	Yes
8 days, painter.	4 — 4 — 4 at 18 mos.	None, screw removed.	Yes

* A: Anatomical result.
S: Symptoms and function.
E: Economic recovery.

† 4 = 100 per cent.
3 = 75 to 99 per cent.
2 = 50 to 74 per cent.
1 = 25 to 49 per cent.
0 = less than 25 per cent.

** Denied military service until screws were removed.

TABLE III

RESULTS IN EARLY INTERNAL FIXATION OF FRACTURES WITH DISPLACEMENT (UNSTABLE)

Time Work Resumed after Operation and Occupation	Result Rated A — S — E * and Period after Operation	Residual Defect	Bony Union (As shown by x-ray)
7 days, porter.	4 — 3 — 4† 9 years	Limitation of 15° of abduction and extension.	Yes
16 days, hotel maid.	4 — 3 — 4 2 years	Limitation of 15° of abduction.	Yes
14 days, kitchen helper.	4 — 3 — 4 3 years	Limitation of 10° of abduction.	Yes
14 days, carpenter.	4 — 4 — 4 4 years	None.	?—one side only.
Uncertain, manual labor.	4 — 3 — 4 6 months	Occasional ache; occasional twinge on adduction.	Yes
14 days, office;	4 — 4 — 4		
28 days, played football.	3 months	Lost to follow-up.	Unknown.
14 days, schoolboy.	4 — 3 — 4 6 months	Limitation of 10° of flexion and extension.	Non-union at 6 mos.; cyst without sclerosis.

* A: Anatomical result.
S: Symptoms and function.
E: Economic recovery.

† 4 = 100 per cent.
3 = 75 to 99 per cent.
2 = 50 to 74 per cent.
1 = 25 to 49 per cent.
0 = less than 25 per cent.

with which pain was relieved and a useful member was regained after internal fixation was a powerful indictment of hypermobility of the fragments as the essential cause of symptoms, and suggested that fibrous fixation sufficient to prevent undue hypermobility of the fragments might be the reason that many ununited fractures remain asymptomatic.

RESULTS

The morbidity was low. The average hospital stay was less than six days. A comfortable and useful hand usually was regained within a week after operation. Except in two instances where the security of the fixation was debatable, all external splints were discarded after a few days. The patients were encouraged to resume hand function and to return to their jobs as soon as symptoms permitted.

Five patients with ununited fractures (Table I) received late internal fixation. All had remained untreated prior to operation. In each, the ununited fracture constituted a major disability, sufficient to prevent work. The rapidity of return to regular work following operative fixation and the ease and comfort with which all of these patients have continued to carry out their normal duties have been surprising, especially since to date none have shown any definite evidence of bone healing (Figs. 4-A through 5-C). It seems improbable at this late date that bony union will ever occur. However, sclerosis has not progressed at the edges of the ununited fracture, but, on the contrary, it has consistently regressed with time and use (Fig. 5-C).

The last lesion listed in Table I presents two points of interest. Operative inspection revealed a large cyst lined with vascular granulation tissues which had excavated each fragment about equally. The internal fixation was secure but faulty, in that the screw engaged the capitate bone, thus blocking mid-carpal motion. Six months after operation,

wrist extension, without pain, remained blocked to 190 degrees; other motions were unimpaired. In addition, over the same period, the cystic cavitation of both fragments continued to regress on each side of the fracture coincidentally with a progressive avascular necrosis of the proximal fragment. The eventual fate of this lesion is not yet established, but it is interesting to speculate upon the source and vascular supply of the new bone obliterating the cystic cavity in the proximal fragment which, by all roentgenographic criteria, is avascular.

Five patients with stable fractures (Table II) were treated by early internal fixation. The technical problems of fixation were simple, and a rapid resumption of normal activities was the rule. As might be anticipated from the nature of the lesion encountered, uneventful bony union occurred in all cases.

Nine patients with unstable fractures (Table III) received early internal fixation. Two of these cases are too recent for evaluation. In seven patients, the postoperative clinical course was as satisfactory as it was for the patients with the stable fractures. Bony union was the rule, but it seemed markedly delayed as compared to the rate of healing in stable lesions. One of these lesions (Fig. 6-A) was characterized by a temporary sclerosis of the proximal fragment, as seen in roentgenograms. Union occurred without necrosis, but the sclerosis, which reached a peak about six months after operation, did not subside completely for almost three years.

SUMMARY

Internal fixation for fracture of the carpal navicular bone is surgically feasible, but requires an exacting technique for the prevention of complications potentially more serious than non-union. The relative merits of nails [1] or screws as fixation devices remain to be established. The small experience reported here warrants no conclusions, but suggests the following:

1. With perfection of operative technique, internal fixation may become the treatment of choice for displaced and unstable fractures of the carpal navicular.

2. The prognosis for any fracture of the carpal navicular may depend as much upon the intrinsic stability of the fragments as upon the level of the fracture, or the vascular status of the proximal fragment.

3. The morbidity of fractures of the carpal navicular is reduced greatly by internal fixation.

4. Rapid relief of symptoms and return of function follow stabilization of an ununited navicular fracture by internal fixation, but bone healing is not to be expected following this procedure alone.

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DISCUSSION

Harold B. Boyd, Memphis, Tennessee: Dr. McLaughlin has given us an excellent paper. I was particularly interested in his discussion of avascular necrosis. There are several fractures where avascular necrosis occurs; three are of marked importance,—fractures of the neck of the femur, fractures of the talus, and fractures of the carpal navicular. For years we treated fractures of the neck of the femur with immobilization and casts, as we are now treating fractures of the navicular. To be sure, our results with fractures of the neck of the femur were much worse than those with cast fixation in fractures of the carpal navicular. I have had no experience with the operation just described, as we have treated these fractures conservatively.

The results with cast fixation in acute fractures of the navicular are satisfactory. However, the treatment is time-consuming, and the patients often get impatient during prolonged cast immobilization. If internal

(*Continued on page 819*)

EXPERIENCES WITH THE STEINDLER FLEXORPLASTY AT THE ELBOW *

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In the Moynihan lecture [8] of 1952 on the Evolution of Modern Tendon Surgery, Steindler's flexorplasty at the elbow is referred to as one of the most important physiological tendon transplantations thus far devised. Steindler published a report in 1918, at a time when he had performed the operation on nine patients; thirty years elapsed before he reported the results in an additional forty cases. Although it is unquestionably accepted as a standard procedure in many orthopaedic centers here and abroad, no discussion of the operation had appeared in any of the major journals until Carroll and Gartland's excellent analysis in 1953 of their experiences at the New York Orthopaedic Hospital. Although the present writers agree with these authors in their strong endorsement of the value of the Steindler flexorplasty, there are sufficient differences in point of view to warrant additional exposition.

This seems to us doubly indicated since, during recent years several alternate procedures have been proposed: the ingenious pectoralis major transplantation of J. M. P. Clark, Bunnell's use of the sternocleidomastoid and his suggested lengthening of the flexor muscles by a strip of fascia lata, and Carroll's shift of the triceps to the biceps insertion. The indications for all these procedures require careful analysis. Our own experience with the Steindler operation, based on the cases treated at the Hospital for Joint Diseases, has taught us so much, yet left us with so many important questions unanswered, that we want to share both our knowledge and our ignorance with readers of *The Journal*.

In general, the operation, which consists in the proximal shifting of the muscles springing from the medial epicondyle of the humerus, is indicated when the biceps and brachialis anterior are paralyzed and the epicondylar muscle group—the pronator teres, the flexor carpi radialis, the palmaris longus, the flexor digitorum sublimis, and the flexor carpi ulnaris—are strong. We have found it important to test with particular care the flexores carpi radialis and carpi ulnaris, since the palmaris longus may be absent and the action of the flexor digitorum sublimis alone is not adequate to produce satisfactory elbow flexion. If it alone is active, flexion of the elbow after transplantation is accomplished only by clenching the fingers and this interferes with the graceful function of the hand. It must always be borne in mind that the patient is primarily interested in hand function, not merely in flexing the elbow. Consequently, if the fingers are paralyzed, the Steindler operation should not be performed unless their function has been restored by preliminary tendon transplantation. This may involve fusion of the wrist to permit satisfactory results following the transplantation of the extensor carpi radialis longus or brevis, extensor carpi ulnaris, or the corresponding flexors of the wrist. Our unsuccessful results have usually been due to overestimation of the strength of the epicondylar muscle group. These muscles must rate at least a strong 3 (on the Lovett scale). A good practical test is to hold the patient's arm at a right angle from the body, thus eliminating the action of gravity, and to observe whether the epicondylar group of muscles can flex the elbow in this position. Unless it can, the transplant will not be effective, and some other reconstructive method must be employed.

In two cases in which the epicondylar muscles were not strong enough to respond to this test we have attempted the combined transplantation of the muscles springing from the lateral epicondyle, the extensor carpi radialis, longus and brevis, and the brachio-

* Read at the Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 22, 1954.

radialis, together with the medial epicondylar group. The results, however, were disappointing, probably because it was impossible to mobilize the lateral epicondylar group sufficiently without damage to their motor nerves. Consequently, alternative operations must be considered.

Of these the most important is the Clark transplantation of a portion of the pectoralis major. Recommended with enthusiasm by Seddon and his coworkers at the Royal Orthopaedic Hospital, it bids fair to rival the Steindler procedure, not only under the conditions just cited, but even when the epicondylar muscle group meets the criteria we have established for effective function after the proximal shift. In doing the Clark operation, it is obvious that the transplanted strip of pectoralis major must retain its nerve supply intact. This is derived from branches of the medial anterior thoracic nerve. From a series of dissections carried out in the anatomical department of St. Bartholomew's Hospital, London, by Dr. Aston under the direction of Prof. A. J. E. Cave, it has been shown that, if a perpendicular line is let fall from the tip of the coracoid process and the third rib is identified, the nerve to the transplant will be found at their junction as it pierces the pectoralis minor. Of course, a powerful pectoral muscle is essential. In almost none of our cases was this condition met; the thoracohumeral muscles were almost always weak and shoulder arthrodesis was a necessary adjuvant in the rehabilitation of the upper extremity. The occasion, however, is bound to arise when either operation may be indicated and the puzzled orthopaedic surgeon will have to choose between the Steindler and the Clark procedures.

Only under unusual conditions will the operator be tempted to employ the Bunnell transplantation of the sternocleidomastoid. This muscle, lengthened by a long tube of fascia lata fastened to the insertion of the biceps, can produce a powerful flexion of the elbow, as was dramatically demonstrated by Bunnell [3]. Aesthetically, however, the result of the operation is bizarre, if not unpleasant, and the procedure should therefore be limited to those few cases in which it is the only method available.

The forward shift of the triceps, presented at the Orthopaedic Section of the New York Academy of Medicine by Dr. Robert Carroll, has also been described by Bunnell [2]. Dr. Carroll's presentation was remarkable in two ways: First, it showed the feasibility and effectiveness of the operation without the use of the fascial graft as recommended by Bunnell; second, it did away with the misconception that a triceps is an absolute necessity for crutch-walking. The patient, who had to rely on two crutches in order to walk, was able to do this by locking his elbow in slight hyperextension and by holding the crutch tightly adducted to the thorax. Despite this fact, however, the sacrifice of the triceps will, we surmise, not be acceptable to most patients or their surgeons, and the operation will probably be reserved for the exceptional case.

THE AIM OF THE STEINDLER OPERATION AND ITS INDICATIONS

We have already mentioned that the patient is primarily interested in the function of his hand. Flexion of the elbow has no importance in itself. He wants above all to bring his hand to his face for eating, shaving, dressing the hair, holding a cigarette, and the numerous other acts of daily living. He wants to do this gracefully and easily and does not wish to pay for this improved function the price of an unsightly defect such as a severe flexion contracture of the elbow. We therefore think that a successful result must conform to the following criteria:

1. The patient must be able to bring his hand to his face;

2. He must be able to do this gracefully, so that his performance does not render him conspicuous;

3. At rest the arm must hang at the side of the body in a natural relaxed position at an angle of no less than 165 degrees.

Therefore, the surgeon must consider the extremity as a whole and fit the flexorplasty

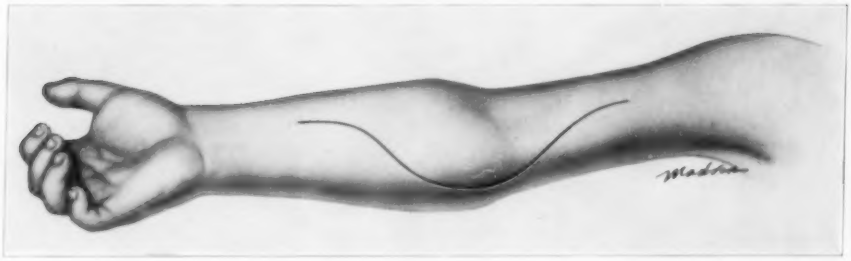

FIG. 1

The skin incision curves gently so that the humerus, the ulnar nerve at the elbow, and the muscles springing from the medial epicondyle are exposed.

into the program of reconstruction of the upper extremity. If the hand muscles are so extensively paralyzed that function cannot be restored by suitable operative procedures, the Steindler tendon shift is contra-indicated. If the medial epicondylar muscles are too weak to flex the elbow when gravity has been eliminated by passive abduction at the shoulder to 90 degrees, the operation should not be attempted. Even if some flexion power is present and this derives solely from the flexor digitorum sublimis, the tendon shift is not likely to be successful, since the patient will be compelled, after the operation, to flex the fingers when trying to flex the elbow, and this will interfere with the gracefulness of the motion. A flail shoulder is, however, no contra-indication, provided the scapular muscles are strong enough to ensure shoulder control following arthrodesis. Above all, the surgeon should not operate unless he himself can supervise the after-treatment. This rule applies particularly to patients with a paralyzed triceps, since it is only by the utmost persistence that a flexion contracture can be avoided. In all cases, however, meticulous postoperative supervision is necessary to prevent a pronation contracture and to secure adequate flexion combined with adequate extension.

TECHNIQUE OF THE STEINDLER FLEXORPLASTY

The operation may be performed with or without a tourniquet. We have never seen a paralysis resulting from a tourniquet applied just below the axilla, but paraesthesia of the fingers, persisting for a week or more, has been observed in a few patients. This may be due in part to the firm pressure dressing of mechanic's waste which must be applied to control oozing after removal of the tourniquet. The swelling induced by this dressing is intensified by the flexed position of the elbow, which must be maintained postoperatively. A consequent necrosis of the skin margins has occurred in some cases. Although this has not interfered with the successful outcome of the operation, it is one of the reasons why we have, during the past few years, given up the tourniquet. True, without it the operation is more arduous and the dissection more difficult, for this is a very vascular region, but at the conclusion of the operation the field is dry, a light dressing may be applied, and the resultant healing is unmarred by skin necrosis. We have thus far not tried the method of operating with a tourniquet which is removed before skin closure, so that the bleeding points may be clamped. If this method is used, the tourniquet must be removed before fixation of the transplant to the humerus, since otherwise bleeding vessels will be obscured by the transplant.

The incision differs from that originally described by Steindler in that it is not placed medially but begins on the anterior aspect of the arm about 7.5 centimeters above the elbow (Fig. 1). This is done to permit adequate exposure of the anterior surface of the humerus to which the transplant is to be attached. The incision swings gently in a medial direction and at the elbow runs just posterior to the epicondyle, thus facilitating exposure of the ulnar nerve. It then curves anteriorly following the direction of the pronator teres

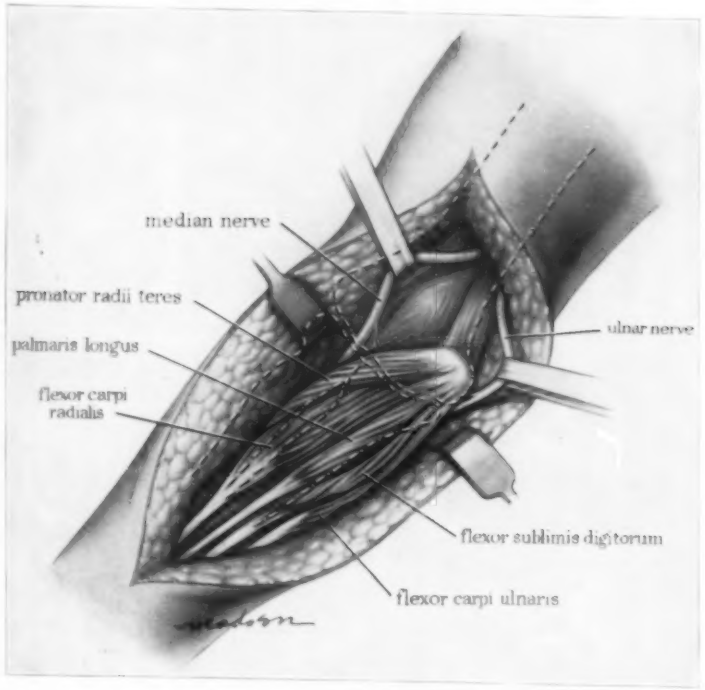

FIG. 2

Fig. 2: Showing dissection to expose the ulnar and median nerves. Some of the branches of these nerves enter the muscles springing from the medial epicondyle. The dotted lines indicate the outlines of the humerus, radius, and ulna.

Fig. 3: A thin flake of the medial epicondyle with the attached muscles is chiseled off. In young children a corresponding portion of the cartilage is cut away with the scalpel.

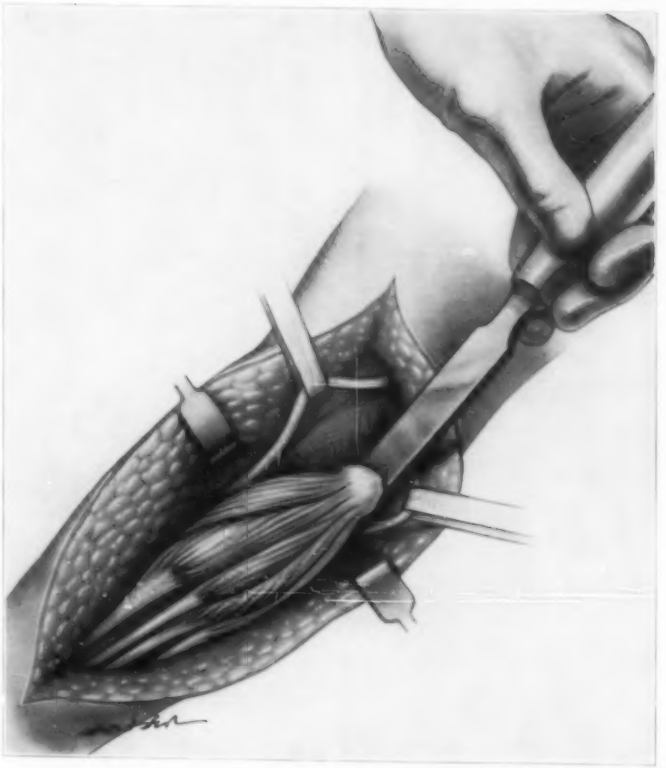

FIG. 3

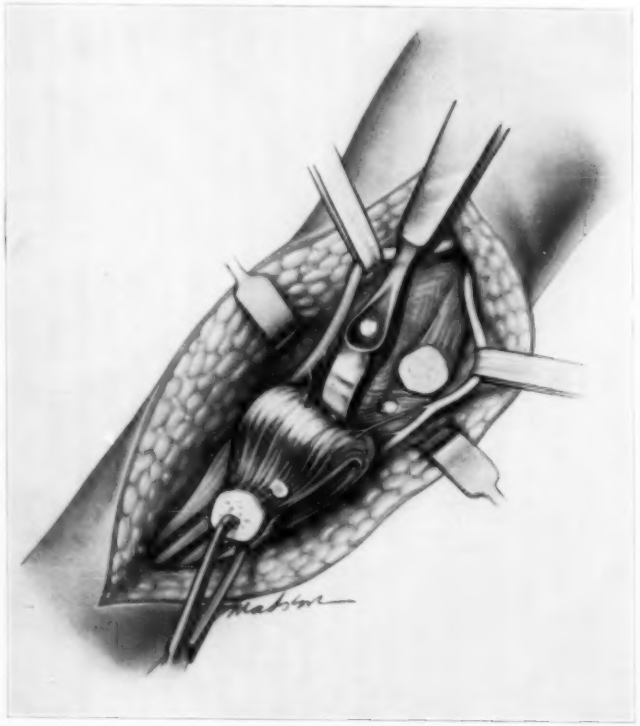

FIG. 4

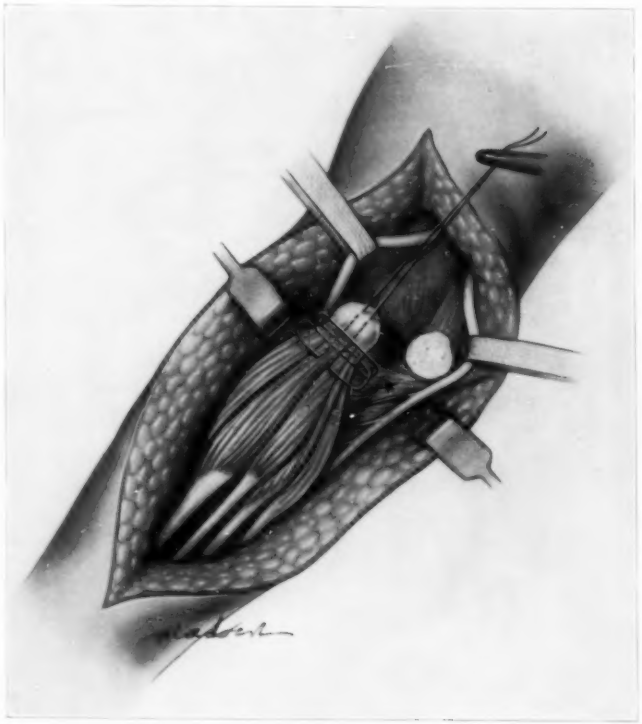

FIG. 5

Fig. 4: The muscles are stripped from the anterior portion of the capsule and from the ulna. The joint capsule is frequently torn because of adhesion of muscle fibers. These tears are inconsequential and are readily sutured without subsequent loss of joint motion. The stripping must be continued to the limit permitted by the motor branches of the median and ulnar nerves. A pledget of gelfoam has been placed over the epicondyle to stop the oozing of blood.

Fig. 5: Showing insertion of the fixation suture (chromic gut, silk, or steel wire). Two transverse and two longitudinal stitches are taken with a suture threaded at both ends with a straight tendon needle.[1] The two free ends perforate the flake of bone or cartilage.

so that it ends about ten centimeters below the elbow in the mid-line of the forearm. In adults the length of the incision may be increased; in young children, somewhat diminished. The skin flap thus formed is retracted gently together with the full thickness of the subcutaneous tissue. By flexing the elbow and externally rotating the arm, the region of the ulnar nerve is readily exposed by undercutting the medial border of the incision. This is further facilitated by placing a sandbag under the opposite hip, in order to turn the patient toward the side of the operation.

The next step is the dissection of the ulnar nerve. Occasionally this nerve is difficult to identify, particularly if the surgeon has confused the medial with the lateral epicondyle—a not impossible mistake if the drapes have been clumsily applied. Usually, however, it is quickly found, isolated, gently lifted from its bed with a tape or suitable blunt instrument, and freed distally until the branches to the flexor carpi ulnaris are seen (Fig. 2). To do this a few fibers of the flexor carpi ulnaris must be divided. The dissection is continued with meticulous care to preserve the delicate but all-important motor branches to a point about five centimeters below the elbow.

Attention is then paid to the median nerve. Like the ulnar nerve, it is exposed above the elbow and dissected downward. When it is lifted gently with a tape (Fig. 2), the emerging motor branches are well demonstrated. The first is the twig to the pronator teres. This is frequently found from 2.5 to 5 centimeters proximal to the elbow. Since the branches all spring from the medial side of the nerve, it is possible to mobilize it even further than the ulnar. Needless to say, the same care must be exercised to avoid trauma to its branches as in the dissection of the ulnar nerve.

Thus far, the operation is essentially a nerve procedure and only surgeons who are adept in peripheral-nerve surgery should undertake it. In the succeeding steps the character of the operation changes, although the protection of the two nerves must be constantly borne in mind until the operation has been completed.

The release of the epicondylar group of muscles is best accomplished by first visualizing the upper border of the pronator teres and tracing it upward to its humeral origin. This will mark the lateral border of the prospective transplant. The medial border has already been indicated by the dissection of the ulnar nerve. The muscle mass thus delineated is freed proximally by cutting away a flake of the epicondyle. In children this can be done with the knife; in older persons with a flat chisel, the blade of which is directed parallel to the fibers of the muscles (Fig. 3). The flake of bone or cartilage is grasped with a suitable clamp and, as traction is made in a distal direction, the muscles are stripped first from the anterior surface of the joint, then from the coronoid process of the ulna. In most cases the muscles are so adherent to the anterior capsule that the joint is opened. Usually the rent is less than 0.6 centimeter. It need cause the operator no concern, but the capsule should be closed at once with a fine stitch. As the muscles are stripped from the ulna with a periosteal elevator (Fig. 4), the assistant puts gentle traction on the median and ulnar nerves, thus demonstrating the motor twigs which the operator must carefully avoid. The stripping process is continued in a distal direction as far as is permitted by the anatomical distribution of the nerves. This step is hazardous, since the nerves are entering from two directions and the operator must therefore shift his focus frequently from the median to the ulnar nerve group and then back again. The more extensive the dissection, the greater can be the proximal shift of the muscles, but under no circumstances should the motor twigs be cut or stretched unduly.

When the operator has accomplished the maximum stripping consistent with safety, the transplant is threaded with the fixation stitch. This may be either of chromic gut, silk, or wire. A "double-header" suture is used, that is, a suture with a suitable straight needle at either end. The muscle mass is transfixed by two transverse and two longitudinal stitches, so placed as to give a firm mechanical purchase (Fig. 5) by the method originally published by Biesalski and Mayer. The elbow is then flexed to 45 degrees and traction is

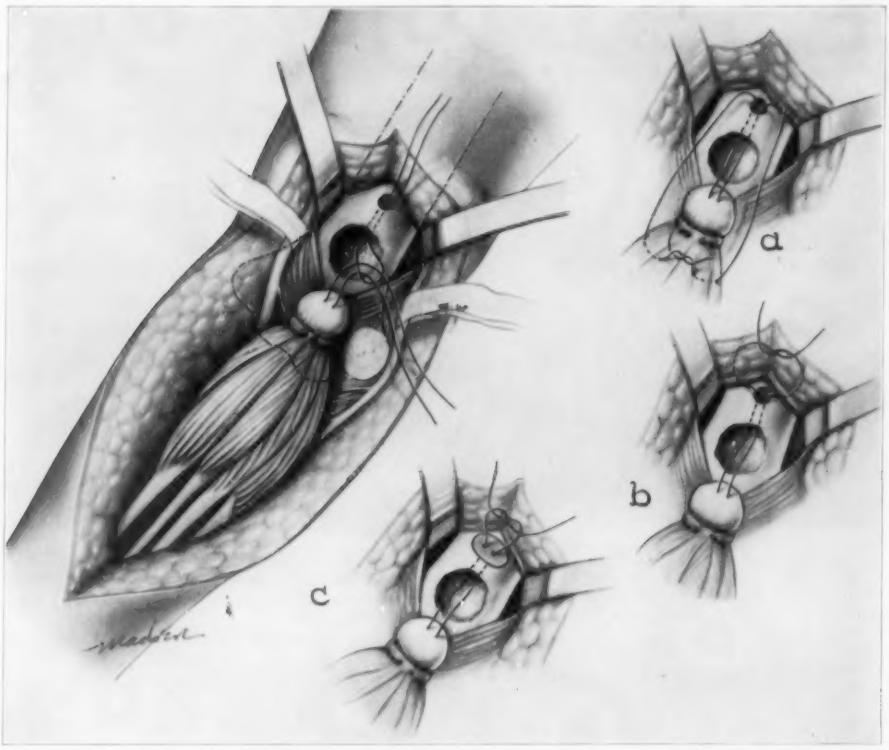

FIG. 6

Showing preparation of the fixation of the muscle-tendon transplant to the humerus. A window has been cut in the anterior cortex of the humerus about five centimeters above the joint, corresponding to the point reached by the transplant when traction is applied during flexion of the elbow. At a point 1.3 centimeters proximal to the window, a small drill opening has been made through which the fixation suture is drawn. By traction on this suture while the elbow is held in flexion, the transplant is drawn within the medullary cavity.

The suture may be fastened in one of three ways, shown in the insets:

a: The ends are passed through the transplant;

b: The ends are passed through the periosteum, the paralyzed brachialis anterior, the biceps, and the fascia proximal to the drill opening;

c: The ends are passed through a small Vitallium button which fits the anterior surface of the humerus at the level of the drill opening. This last method is the simplest and most effective.

exerted on the transplant to determine how far above the elbow it will reach. This is usually between 5 and 7.5 centimeters. In the original Steindler technique, the transplant was fastened to the fascia on the medial aspect of the arm. We have modified this step by attaching the transplant to the humerus. Two reasons have impelled us: First, the insertion of tendon to bone is stronger than insertion to fascia; second, the more lateral the insertion, the less the pronatory effect of the muscles. Since the possibility of a pronation contracture is one of the dangers of the operation, this second reason is a compelling one and has unofficially been given Steindler's approval.

Various methods of attaching the transplant to the bone may be used. Our technique is as follows: The median nerve, together with the brachial vessels, is retracted medially and the atrophied fibers of the biceps and brachialis anterior are slit longitudinally until the periosteum is exposed over the anterior aspect of the humerus. The periosteum is incised for about five centimeters and is peeled off the bone, which is exposed for about 3.8 centimeters by the insertion of Lane retractors. The median and musculocutaneous nerves are protected from undue pressure by the periosteum and the split

muscles. An opening is then made in the humerus, nearer the lateral border than the medial, at that point to which the transplant reaches when the elbow is flexed (Fig. 6). The humeral cortex is pierced with a one-eighth-inch drill and the opening is enlarged by one or more drill openings which are connected by gouge, rongeur, and curette until the opening is large enough to admit the transplant with its flake of bone into the medullary cavity. Another drill hole is then made about 1.3 centimeters proximal to the large opening and a guide suture is passed from one to the other, the loop of the suture projecting from the larger opening (Fig. 6). The two free ends of the fixation suture are passed into the loop of the guide suture and are drawn into the large opening and out of the small

FIG. 7-A

Madeleine D. Showing maximum extension (about 110 degrees) of the elbow six weeks after operation. The physician in charge of postoperative physical therapy had not realized the necessity for stretching the transplant.

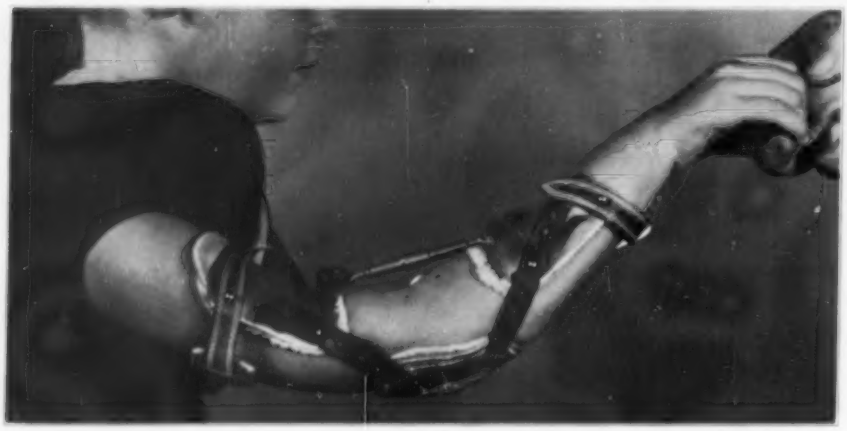

FIG. 7-B

drill opening. A trial is then made to see whether, when the elbow is flexed and traction is exerted on the suture, the transplant will be drawn into the medullary cavity. Sometimes the opening must be enlarged somewhat in a distal direction or modified in some way to permit the secure lodgement of the muscles. The operator must inspect the median and ulnar nerves to be sure that they are not subjected to undue tension or twisting and that the motor twigs are not injured. The suture is not fastened as yet since, if that were done, the surgeon would have considerable difficulty in closing the distal half of the wound. If a tourniquet has been used, it should be removed at this point and all bleeding points should be ligated. The distal part of the wound is then sutured up to the bend of the elbow; usually subcutaneous and skin stitches suffice.

The final step is the fixation of the transplant to the humerus. We have used three

FIG. 7-C

Figs. 7-B and 7-C: The same patient, shown wearing a turnbuckle extension brace. The essential feature in the construction of this brace is that the pressure pads fit the contour of the arm and pivot during extension, so that the pressure is evenly distributed.

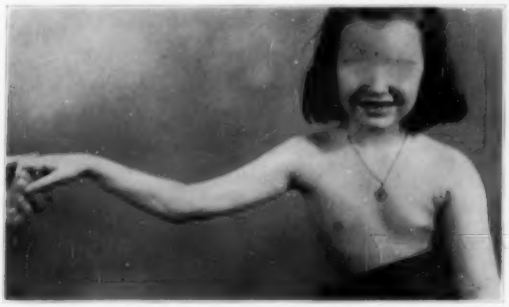

FIG. 7-D

FIG. 7-E

Photographs of the patient after six weeks of treatment with the turnbuckle brace. At that time she could extend the elbow to 165 degrees. No power of flexion was lost during this period.

methods, all of them with success in most cases, but with an occasional failure which emphasized the importance of meticulous accuracy. In all three, the two free ends of the suture are drawn tight, with the elbow at 60 degrees, to bring the transplant within the medullary cavity. In the first method, several stitches are taken with each end of the suture, to which a curved needle has been attached, through the transplanted muscles. When the suture is tied, the transplant is held securely within the cavity of the humerus (Fig. 6, *a*). In the second method the two curved needles traverse, first the fibers of the brachialis anterior and biceps, then the fascia and subcutaneous tissue proximal to the point of bony fixation (Fig. 6, *b*). In the third (Fig. 6, *c*) a small button of Vitallium, shaped to fit the anterior surface of the humerus, is used. The stitches are brought through the two holes of the button and tied with the requisite tension. Although we have used this method in only one case, it appeals to us as the simplest and most effective.

The proximal portion of the wound is then sutured and a light dressing is applied, as well as a posterior plaster-of-Paris splint holding the arm in flexion of about 60 or 70 degrees and in maximum supination. There should be no undue pressure on the elbow,

either anteriorly or posteriorly. The radial pulse should always be palpated and the color of the fingers should be noted; any abnormality calls for an immediate modification of the dressing, which may be too tight at some place.

DISCUSSION OF OPERATIVE TECHNIQUE

We have given this description of the operation in detail because nowhere in the literature have we found an accurate account of this important procedure. Several features call for further discussion.

First, *the incision:* This is designed for the double exposure of the ulnar and median nerves, as well as the anterior aspect of the humerus. We have tried other incisions but have always found this one to be the best. The positioning of the patient also is important in making the ulnar nerve easily accessible. Turning the patient 25 or 30 degrees toward the side of the operation, combined with external rotation, usually suffices. If, however, the surgeon cannot see the region easily, lifting the arm in the sagittal plane with the elbow flexed will bring it into view. An assistant must hold the arm in this position until the nerve has been exposed above the elbow and lifted out of its bed with a tape. As soon as this has been done, the arm may be lowered, since the nerve is easily visible below the elbow when the arm rests on an arm board or a suitable small table. As in all peripheral-nerve surgery, an atraumatic technique is imperative; the nerve should never be grasped with forceps or bruised with retractors, and it should be kept moist with saline solution or some other suitable fluid such as dilute penicillin or terramycin solution.

Second, *the choice of the muscles to be transplanted:* We believe it advisable to use all the available muscles, that is, the pronator teres, the flexor carpi radialis, the palmaris longus, the epicondylar and ulnar portions of the flexor digitorum sublimis, and the anterior portion of the flexor carpi ulnaris. Eyler, in 1950, advocated omission of the flexor carpi ulnaris, since the surgeon can then work in a cleavage plane between the flexor sublimis anteriorly and the flexor profundus and flexor carpi ulnaris dorsally,—that is, in the so-called "internervous plane". The authors have had no experience with Eyler's method, because thus far they have found it advantageous to include the anterior portion of the flexor carpi ulnaris in the group of transplants, but it deserves further study. It may facilitate the technique without detracting from the effectiveness of the operation. The freeing of the muscles, once the epicondylar attachment has been severed, is best accomplished with a periosteotome shaped to conform to the contour of the coronoid process (Fig. 4). Sometimes a troublesome bleeder is encountered near the base of the process. In only one instance have we seen a weakness of the muscles after stripping; this was a temporary paresis of the flexor sublimis of the index finger, which cleared up after three months.

Third, *the technique of fixation of the transplant:* We have already given our reasons for preferring attachment to bone rather than attachment to fascia. Bunnell has published an important modification of the insertion into bone,—that is, lengthening the transplant by attaching a strip of fascia lata which, threaded with a wire pull-out stitch, is brought through the humerus and sewed to a button on the posterior surface of the arm. Thus far, we have never used this method, but it may be a means of simplifying the problem of adequate extension of the elbow.

Fourth, *the placement of the ulnar nerve:* We have often wondered whether, since the nerve is freed for a distance of several centimeters, an anterior transposition might be advisable. The temptation to shift the nerve was particularly strong in those cases in which it had slipped out of its groove and lay without tension on the anterior surface of the elbow. Certainly the good results secured in many cases of late ulnar neuritis due to malunion of a fracture seemed convincing proof that no harm would occur and that there might be some advantage in lessening the tension on the nerve. In the one case, however, in which we shifted the nerve, the result was disastrous; a complete paralysis of the nerve

FIG. 8-A

FIG. 8-B

These photographs illustrate the graceful use to which the arm can be put after transplantation. This patient looks after her baby and does all the work in her home. Before the operation she had regarded her arm as useless.

FIG. 9-A

FIG. 9-B

These photographs illustrate the ideal range of motion from complete flexion to complete extension. The patient, who had had poliomyelitis in 1932, had total paralysis of the biceps and brachialis anterior, as well as of the scapulohumeral muscles. In 1937 a Steindler transplantation and shoulder arthrodesis were performed. Since then he has had normal function of the arm. He is now studying medicine. He can flex the elbow against a resistance of forty-two pounds.

ensued which was not improved by a secondary neurolysis. At this operation, performed three months later, the nerve was found to be bound down by scar tissue and it had degenerated to a thin strand of tissue. It may be that it is unfair to judge by this case, since it was also the only one in the series in which an arthroplasty of the elbow was combined with the Steindler procedure. The resultant range of motion (160 to 135 degrees) was unsatisfactory and we are therefore opposed to this combined procedure, as well as to transposition of the nerve.

AFTER-TREATMENT

As a rule, patients may leave the hospital two or three days after surgery. How long should immobilization in acute flexion continue? There is a difference of opinion. In Carroll and Gartland's series the average was six weeks. This seems to us unduly long, since the research of Biesalski and Mayer showed conclusively that union between tendon and bone occurs in three weeks. That has been the period in our cases, but we think that, when the triceps is completely paralyzed, the immobilization period should be shortened to two

FIG. 10-A

FIG. 10-B

This patient, a resident in orthopaedics, had had poliomyelitis in October 1948 after volunteer service with the National Foundation for Infantile Paralysis during the epidemic in North Carolina. The right upper extremity was totally paralyzed. Seven months later the forearm muscles had recovered, but the elbow and scapulohumeral muscles were still rated zero. In order to speed his rehabilitation, it was decided not to wait the customary two years but to perform the Steindler transplantation in April 1949 and the shoulder arthrodesis in June of the same year. He was able to resume his position in September 1949. He now has complete range of elbow flexion and extension. His strength is sufficient to enable him to remove plaster-of-Paris dressings, to reduce fractures, and to hold heavy weights, as shown in the photograph. He has learned to use his flexor carpi ulnaris and extensor pollicis longus as supinators, so that he can supinate the needle holder in suturing a wound. He uses the arm smoothly and naturally for all practical purposes.

weeks. Otherwise, it is very difficult to straighten the elbow (Fig. 7-A). The stretching should be done gently by a therapist accustomed to the postoperative treatment of tendon transplants and should be combined with exercises to develop the strength of the flexors. From the outset, the patient should be taught to supinate as much as possible. Some pronation is inevitable, but by development of the flexor carpi ulnaris and the extensor pollicis longus (if one is present) this pronating effect of the pronator teres can be partly balanced. The exercises should be done several times daily. Only if the interest of the patient is engaged, can this phase of the treatment be carried out effectively; actually, the ultimate result is as much dependent on the cooperation of the patient as on the skill of the surgeon. After the fourth week, a light turnbuckle brace is worn at night to help straighten the elbow. The brace must be so constructed that the pressure of the two cuffs is evenly distributed over a broad surface. This is done by attaching them to pivots (Figs. 7-B and 7-C) so that, as the elbow is extended, the cuffs will automatically shift their position. If the cuffs were rigidly attached, one of the edges would cut into the patient's arm and prevent effective use. It is important for the surgeon to realize that the length of the muscle fibers of the transplant must actually be increased if the ultimate goal—normal motion of the elbow—is to be achieved (Figs. 7-D and 7-E). The less strength there is in the triceps, the harder this is to accomplish. This period of exercise and stretching should be continued for weeks and even months until the maximum range and strength of motion has been secured and until the patient is able to use the arm gracefully (Figs. 8-A and 8-B). It cannot be emphasized too strongly that the success of the operation depends not merely on accurate technique but on painstaking postoperative care, in which the surgeon, the physical therapist, the brace-maker and, above all, the patient himself, must each contribute his share of enthusiasm and effort (Figs. 9-A through 10-B).

ANALYSIS OF RESULTS

It is obvious that our aim does not correspond with that expressed by Carroll and Gartland. They accept a flexion contracture of 40 degrees as a good result. The authors are not satisfied unless extension to 165 degrees is combined with flexion to 50 degrees. In those patients with the best results, both extension and flexion have been complete

TABLE I

ANALYSIS OF RESULTS

	Patient	Flexion (*Per cent.*)	Loss of Extension (*Per cent.*)	Loss of Supination (*Per cent.*)	Total (*Per cent.*)
Excellent results	J. G.	100	4	0	96
	I. K.	100	0	2	98
	W. G.	100	0	0	100
	B. W.	100	3	0	97
	W. D.	100	0	3	97
	L. K.	100	3	0	97
	R. K.	100	1	0	99
	W. H.	100	2	0	98
	M. D.	100	0	5	95
	S. R.	100	0	5	95
	L. C.	100	0	2	98
Good results	M. M.	100	13	0	87
	Allen A.	90	0	4.5	85.5
	Adelaide A.	95	3	6	86
	E. B.	100	3	6	91
	R. D.	100	9	5	86
Fair results	L. M. right	100	15	4	81
	left	100	15	4	81
	J. S.	85	0	4	81
	J. G.	80	1	3	76
Poor results	I. N.	65	1	3	61
	A. W.	65	5	2	58

(Figs. 9-A through 10-B). We have established as a guide a simple mathematical formula in which the ranges of flexion, extension, and supination have been assigned certain values, as follows:

RANGE OF FLEXION AGAINST GRAVITY

Up to 50 degrees	100 per cent.
Up to 70 degrees	90 per cent.
Up to 90 degrees	80 per cent.
Less than 90 degrees	65 per cent.

From this figure deductions are made. The first is for loss of extension; 1 per cent. is subtracted for each 5 degrees less than 165 degrees. The second deduction is for loss of supination. We felt that complete supination could be achieved so seldom that a loss of 45 degrees should be accepted as a good result. Therefore, we have subtracted 1 per cent. for each 10 degrees less than 45 degrees of supination.

An example will make this formula quite understandable. Patient X is able to flex the elbow against gravity to 70 degrees. He is therefore rated as having a result of 90 per cent. Extension, however, is possible only to 140 degrees, which is 25 degrees less than the accepted standard; consequently 5 per cent. is subtracted from 90 per cent. and, since his supination is 20 degrees less than the standard, he loses an additional 2 per cent. Thus, his score is 83 per cent. We have graded a score of 95 per cent. or over as excellent, between 85 and 94 as good, from 75 to 84 per cent. as fair, and below 75 per cent. as poor.

In studying our cases, we have been greatly hampered by our inability to locate the patients, a difficulty which we share with all those who have attempted a follow-up research extending over many years. The actual number of patients operated upon is considerably larger than that reported here, but we have found it advisable to consider only those whom we ourselves have been able to re-examine. In Table I the percentages

for each patient are given. We have purposely omitted the age and sex of the patients, since neither had any bearing on the results. The youngest was four years old and the oldest was thirty-two years old.

The analysis of these cases has been of considerable significance. Our first question was naturally, why the poor results? In the first case, I. N., the explanation is obvious: This patient had had an extensive comminuted fracture of the elbow with resultant loss of flexion to less than 135 degrees. We attempted to combine an arthroplasty with the Steindler operation. Had we done the arthroplasty first, and the tendon shift as a secondary operation, we probably could have secured satisfactory results from both. In the second case, A. W., the patient, who was a clerical worker with bilateral upper-extremity paralysis, had asked us not to attempt to secure normal flexion, since all he needed was flexion to about 110 degrees. Consequently, we shifted the muscles too short a distance above the elbow to secure adequate leverage.

Our next question was: Why did some patients lose a grade because of loss of extension? The answer was comparatively simple: Invariably these patients had a paralyzed triceps and the period of immobilization had been too long. It is our present opinion that in such cases immobilization should be maintained only for two weeks and that stretching should then be begun with great care, so that the transplant is not torn away from the bone.

Third, we considered the loss of supination. This is one of the inherent dangers of the operation. We try to minimize it by attaching the muscles as far laterally as possible, but even with this precaution a strong pronator teres is bound to pronate the forearm, since its chief supinator opponent—the biceps—is invariably paralyzed. The only way to overcome this difficulty has already been mentioned in the section on after-treatment: The patient must be taught from the outset of treatment to utilize the flexor carpi ulnaris and the extensor pollicis longus, both of which have a supinatory component, to prevent the pronatory effect of the pronator teres. That this can be done by adequate post-operative training has been demonstrated by most of the patients in the group with excellent results.

THE PLACE OF FLEXORPLASTY IN RECONSTRUCTION OF THE UPPER EXTREMITY

In discussing the aim and indications of the operation we have already pointed out that it must be regarded as only one step in the restoration of function to the arm. The timing of the various operations is important. First, the work on the hand should be completed; the most frequent operation in our series has been the Bunnell tendon transplantation for paralysis of the opposing muscles of the thumb. Arthrodesis of the wrist has enhanced the effectiveness of the flexorplasty in selected cases. The Steindler flexorplasty or its equivalent should be performed next. Finally, when adequate elbow function has been secured, arthrodesis of the shoulder is performed. Thus far, we have not had occasion to do a trapezius transplantation in conjunction with a Steindler operation. The stability of the shoulder has greatly increased the effectiveness of the flexorplasty and we have recommended it in most of our patients. Because of paralysis or weakness of the pectoralis major in almost all of our cases, we have thus far not performed the Clark operation.

We believe that the operation can be performed at any age, provided the patient is old enough to cooperate in the after-treatment. Our youngest patient was four years old; she secured an excellent result. Our oldest patient was thirty-two years old, but we can see no contra-indication to operations on older persons.

Another more controversial question is how long a period should elapse between the onset of poliomyelitis and the execution of the operation. In most instances we followed the conventional rule of waiting two years, but in one case we waited only seven months. The patient, a young surgeon, was completely blocked in his professional development by

paralysis of the elbow flexors and shoulder muscles. Since the hand had recovered but not a trace of strength had returned to the elbow flexors, we decided that further delay would be unwise. After the Steindler operation and arthrodesis of the shoulder, the surgeon was able to resume normal professional activity and was thus saved almost a year and a half of waiting time.

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DISCUSSION

Dr. Arthur Steindler, Iowa City, Iowa: I would not be human if I did not feel a warm glow of satisfaction over the fact that Dr. Mayer was kind enough to elevate my humble contribution to the dignity of a special presentation. It did not take long to plan technical considerations of this idea, but what is behind it was the necessary recognition that we are now dealing, probably for the first time, with a complete reversal of the kinetic chain which activates the function of the hand. It is no longer a free peripheral organ. Here is a situation in which the muscle is called upon to exercise its force in a central direction. In the lower extremity we are familiar with this. We know that the soleus can extend the knee and even the hamstrings can do so under certain conditions, provided that the extremity is fixed and the muscle is thus acting in a close kinetic chain. This fact had to be considered before a concept of the validity of the method could be arrived at.

The reversal occurs by reason of the fact that, although the fingers are allowed to move, the wrist must be held stable. Every muscle which flexes the wrist exercises also a central rotatory effect in inverse proportion to the mass to be moved. The wrist must be fixed and for this reason one of the conditions is the intact state of the flexors of the wrist. Athough the operation has its drawbacks, and I am the first to acknowledge it, I am satisfied to see the method arrive at the ripe age of over thirty years. At the same time, it has certain weak points; for instance, it has a definite tendency to cause pronation. If the extensors of the wrist are also used for transposition, the equilibrium between the flexors and extensors of the wrist may be jeopardized. We have tried to solve this problem by using the flexor carpi ulnaris. It has the least rotatory effect on the elbow, being located so close to its axis. It can be isolated and led diagonally over the dorsal surface of the forearm and fixed dorsally to the end of the radius, and thus become a supinator.

The other point is that, even with transplantation of the muscle to a point in the humerus about 2.8 to 5 centimeters higher, its rotatory effect is not comparable in strength to the effect which could be obtained if the brachialis were active.

We do not like to do the operation unless we are quite sure that the forearm muscles are in good condition. I can only state that I admire a great deal Dr. Mayer's refinements of the operation. The method has gained in value by these, but it is not the only one which might be used. The method which I would recommend for cases in which the forearm flexors are not available is the long-range transplantation of the sternocleidomastoid devised by Dr. Bunnell.

(*Continued on page 858*)

THE MUSCLE-PEDICLE BONE GRAFT IN HIP FUSION

BY JOE B. DAVIS, M.D., PORTLAND, OREGON

To keep the blood supply of transplanted tissue intact is one of the basic principles of surgery. The hip joint, with the adjacent ilium, lends itself well to transplantation of bone with an attached muscle pedicle through which the periosteal blood supply can be maintained.

Many attempts to use pedicle bone grafts have been recorded. In 1891 Phelps reported his unsuccessful attempt to bridge an osteomyelitic defect in the tibial shaft of a young boy with a living pedicle from the leg of a dog. More practical use of this principle of surgery was made by Curtis and others, who transplanted the fibula into the tibia.

In 1911 Hibbs [5] reported a technique for knee fusion in which he left the patella attached to its tendinous investments. However, he was of the opinion that this graft had no advantage over the free patellar graft. In 1926 he reported a technique of hip fusion in which he used the greater trochanter as a pedicle bone graft.[6] In this procedure he used a relatively avascular tendinous pedicle.

Watson-Jones in 1933 described a method of using a pedicle bone graft for repair of cranial bone defects, and Cole in 1940 reported the use of a pedicle bone graft in treatment of non-union of the mandible.

In 1942, Hellstadius presented his observations on transplantations of cortical bone

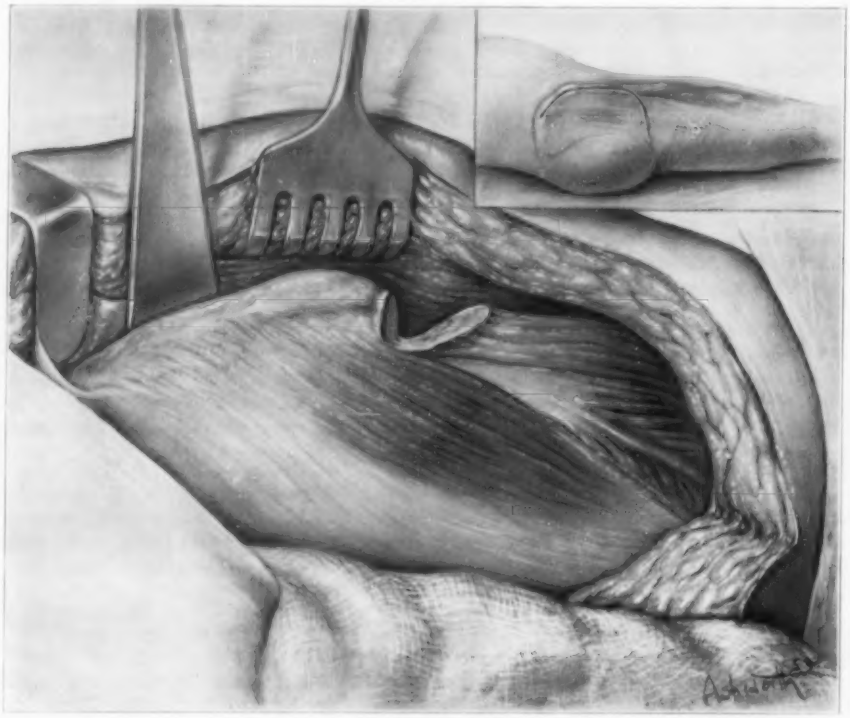

FIG. 1

The skin incision is shown in the inset. The incision has been extended to the crest of the ilium. The sartorius has been detached and the osteotome has been placed in preparation for detaching the bone graft.

FIG. 2

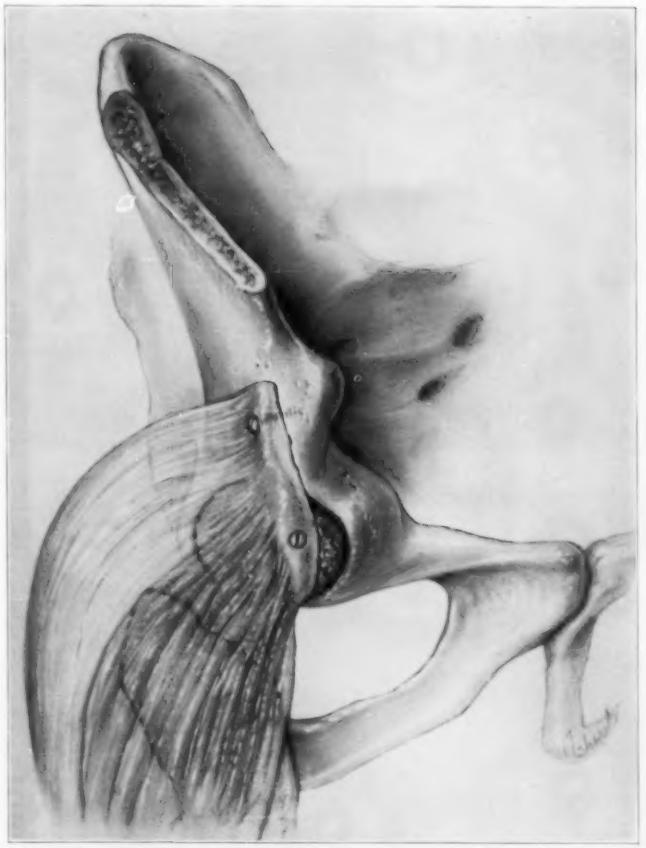

FIG. 3

Fig. 2: The cartilage has been removed from the femoral head and acetabulum. A slot has been prepared for reception of the pedicle bone graft.

Fig. 3: An intertrochanteric osteotomy has been carried out. The bone graft has been placed in the slot and secured with two screws.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 1, a man, aged seventy. The preoperative roentgenogram showed degenerative arthritis (malum coxae senilis).

Fig. 4-B: Roentgenogram made two years and nine months after surgery. Only a partial denudation of the intra-articular cartilage had been done in this case.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 2, a man, aged sixty-four. The preoperative roentgenogram showed degenerative arthritis (malum coxae senilis).

Fig. 5-B: The roentgenogram made twelve weeks after operation showed bony ankylosis.

from extremities and tendon insertions in rabbits. He concluded that there was no particular difference between the reaction or fate of this bone graft and the reaction of standard autogenous bone transplants.

FIG. 6-A

FIG. 6-B

Fig. 6-A: Case 3, a man, aged thirty. The preoperative roentgenogram showed degenerative arthritis resulting from fracture-dislocation.

Fig. 6-B: Fifteen weeks after operation there was bony ankylosis.

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 4, a man, aged fifty-five. The preoperative roentgenogram showed degenerative arthritis (malum coxae senilis).

Fig. 7-B: Fourteen months after operation there was bony ankylosis.

FIG. 8-A

FIG. 8-B

Fig. 8-A: Case 5, a woman, aged fifty-eight. The preoperative roentgenogram showed degenerative arthritis. Arthroplasty had failed to relieve this patient's pain. The Smith-Petersen cup had been removed.

Fig. 8-B: Bony ankylosis failed to occur after seven months of immobilization in a plaster cast. The graft had been improperly applied to the ilium.

FIG. 9-A

FIG. 9-B

Fig. 9-A: Case 6, a man, aged twenty-three. The preoperative roentgenogram showed degenerative arthritis resulting from traumatic dislocation.

Fig. 9-B: Bony ankylosis twelve weeks after fusion.

FIG. 10-A

FIG. 10-B

Fig. 10-A: Case 7. A man, aged thirty-three. The preoperative roentgenogram showed degenerative arthritis apparently resulting from old Perthes' disease.

Fig. 10-B: Bony ankylosis twelve weeks after operation.

Davis and Taylor in 1952 described their results with transplantation of muscle-pedicle bone grafts in dogs. They transplanted to one hip cancellous bone from the anterior crest of the ilium with a muscle-belly pedicle. To the opposite hip they transplanted a free autogenous graft as a control. Recovery of specimens of different ages revealed that the muscle-belly pedicle bone graft contained some elements of living bone which were not present in the free autogenous bone graft employed as a control. The difference in the observations made by Hellstadius and by Davis and Taylor may be explained by the fact that two entirely different types of experimental studies were carried out. The trochanteric and diaphyseal bone selected for transplantation by Hellstadius derive a very minimal supply of blood from the periosteum.

The results of these experimental studies induced the author to attempt transplantation of bone within the limits of its periosteal blood supply in arthrodesis of the hip joint. The procedure consists in an intra-articular arthrodesis supplemented by a muscle-pedicle bone graft and an intertrochanteric osteotomy.

TECHNIQUE

An anterior (Smith-Petersen) incision is started 7.5 centimeters behind the anterior superior iliac spine; this is extended along the anterior crest of the ilium to the anterior superior iliac spine and is curved downward to end near the base of the greater trochanter. The incision is then carried to the iliac crest and the space between the sartorius and the tensor fasciae latae muscles is identified. The sartorius muscle is detached from its origin, secured by suture, and retracted out of the wound (Fig. 1). The superior rim of the anterior crest of the ilium is then approached. By subperiosteal dissection, the aponeurosis of the

FIG. 11-A

FIG. 11-B

FIG. 11-C

Fig. 11-A: Case 8. A man, aged fifty-six. The preoperative roentgenogram showed degenerative arthritis (malum coxae senilis).

Fig. 11-B: The roentgenogram showed bony ankylosis twelve weeks after operation.

Fig. 11-C: Roentgenogram made eight months after surgery.

abdominal muscles and the iliacus minor are separated from the superior and medial surface of the ilium. This preparation of the field permits removal of a bone graft and leaves the external muscles intact.

By means of a vertical osteotomy at the posterior limb, the anterior 6.4 centimeters of the crest of the ilium is removed to a depth of 2.5 to 4 centimeters, depending on the need in the particular case. During this part of the procedure, the osteotome is, of course, directed from inward to outward. After the bone has been freed, it has a muscle pedicle consisting of the tensor fasciae latae and the anterior fibers of the glutaeus medius and glutaeus minimus. By sharp dissection in the course of the fibers of the glutaeus medius a muscle pedicle is developed.

At this stage of the operation, the surface of the bone graft is covered with blood coming from vessels in the muscle pedicle. This bleeding is controlled by packing of the donor area and the bone graft with laparotomy sponges.

When hemostasis has been assured, the direct head of the rectus femoris muscle is detached and the capsule is opened. The hip joint is then dislocated and the cartilage is removed from the acetabulum and the femoral head. The femoral head is then reduced into the acetabulum and the direct head of the rectus femoris muscle is reattached to its place of origin. In preparation of the site for placement of the graft, a slot is made in the ilium superior to the acetabulum and a groove is made across the neck of the femur (Fig. 2). The exact location of these incisions can be ascertained by placing the graft across the area it is to cover.

An intertrochanteric osteotomy is then performed through the lower limb of the

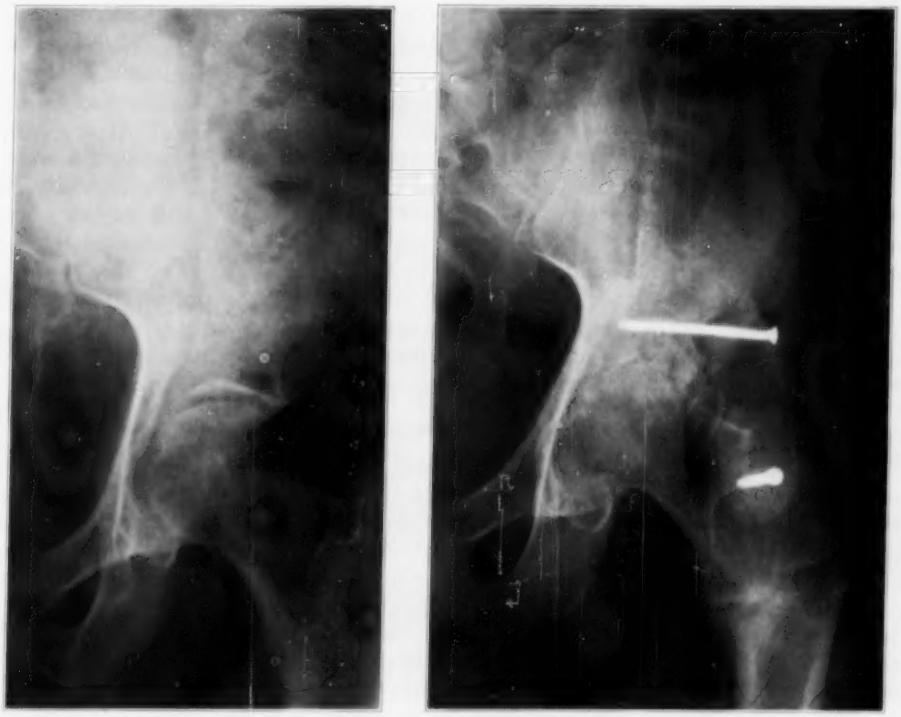

FIG. 12-A FIG. 12-B

Fig. 12-A: Case 9. A man, aged forty-six. The preoperative roentgenogram showed degenerative arthritis from fracture of the acetabulum.

Fig. 12-B: Bony fusion was present twelve weeks after operation.

TABLE I

SUMMARY OF RESULTS OF NINE HIP FUSIONS IN WHICH MUSCLE-PEDICLE BONE GRAFTS WERE USED

Case	Sex	Age	Diagnosis	Time Required for Bony Ankylosis (*Weeks*)	Follow-up (*Months*)
1	M	70	Degenerative arthritis, malum coxae senilis.	14	33
2	M	64	Degenerative arthritis, malum coxae senilis.	12	34
3	M	30	Degenerative arthritis, post-traumatic.	15	24
4	M	55	Degenerative arthritis, malum coxae senilis.	14	12
5	F	58	Degenerative arthritis, painful arthroplasty.	Failure *	7
6	M	23	Degenerative arthritis, post-traumatic.	12	7
7	M	33	Degenerative arthritis, old Perthes' disease.	12	20
8	M	56	Degenerative arthritis, malum coxae senilis.	12	12
9	M	46	Degenerative arthritis, fractured acetabulum.	12	8

* No ankylosis at the end of seven months.

incision. The purpose of this procedure is to obtain optimum immobilization of the area of fusion. Adjustment of the position of the extremity as desired is facilitated through the osteotomy site. Care should be taken not to place the osteotomy site lower than the lesser trochanter because of the danger of non-union. Mechanical fixation at the osteotomy site should not be carried out. The osteotomy is done before the graft is secured, in order to avoid disturbance of the graft. After this procedure has been accomplished, the graft is secured by Vitallium screws, one being placed through the graft into the ilium and another across the graft and the femoral neck (Fig. 3). The screws will thus be at about a 90-degree angle to each other and fixation will be firm.

The distal portion of the wound is closed anatomically. The sartorius is attached to the remnants of the hip-joint capsule and the femoral ligament. A coagulant membrane is placed over the donor bone area. The abdominal muscles are sutured to the glutaeus medius. The skin is closed without drainage.

POSTOPERATIVE CARE

Immediately after the operation the patient is placed in a standard hospital bed and eight pounds of skin traction is applied to the affected extremity. This traction is continued for seven to ten days. At the end of this time the patient is placed in a double spica cast, long on the side operated upon and short on the well side. There are a number of advantages in waiting several days before applying the spica cast. One is that the patient can be cared for more easily after operation. Another is that the cast can be applied so that it is worn with more comfort. Still another advantage is the possibility of adjusting the position of the extremity more accurately through the osteotomy site when the paraphernalia of the operating room are not present.

The original spica cast is maintained for six weeks. It is then changed to a double spica cast which extends only to the knee on each extremity. The patient is made ambulatory with walkers, parallel bars, or crutches, depending on his physical prowess. Knee motion is maintained by physical therapy.

When this series was first started, a long spica cast was used until fusion at the hip was solid. It was noted, however, that early use of the short double spica cast gave more prompt return of knee motion.

The short double spica cast is worn until the fused hip has bony union. In this series the average time between operation and bony ankylosis was thirteen weeks. Fusion was determined by clinical testing and x-ray examination.

After the removal of plaster, the patients are made ambulatory as rapidly as their general physical condition will allow. This varies somewhat with the age of the patient, but walking is started with crutches and progresses to full, unassisted ambulation as soon as possible. It appeared in this series of cases that early mobilization of the knee facilitated early walking.

POSTOPERATIVE COMPLICATIONS

There were no more complications after this procedure than after any other major hip operation. Some of the patients had urinary retention, which was relieved by catheterization. Two had moderate ileus, which was controlled by mechanical rectal therapeutics. One patient had peroneal palsy from improper application of the plaster cast; he recovered. There was no instance of surgical shock or infection.

EVALUATION OF RESULTS

The procedure described was carried out on nine patients, eight men and one woman. Their ages ranged from twenty-three to seventy years. Each patient had degenerative arthritis of the hip from one cause or another.

The results are summarized in Table I. It will be noted that the woman failed to obtain bony union. The pedicle graft in this patient had been placed across the anterior aspect of the hip joint. It is believed that ankylosis failed to take place because the iliac bone was not adequate for reception of the graft. Moreover, as a result of the previous femoral-head resection, there was a loose fit between the femoral neck and the acetabulum.

If the one failure is excluded, the average time for bony ankylosis of the hip was thirteen weeks. The first patient was operated on thirty-four months ago. Hence, thirty-four months is the longest follow-up period.

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MUSCLE-PEDICLE BONE GRAFTS *

BY JOEL HARTLEY, M.D., AND NORMAN SILVER, M.D., NEW YORK, N. Y.

From the Orthopaedic Service of Mt. Sinai Hospital, New York City

Can autogenous bone grafts be kept viable if a muscle pedicle is permitted to remain attached? We know from a large number of previously reported observations that free autogenous bone grafts die first and then are gradually replaced by new bone. Absorption progresses concomitantly with the development of newly formed living osseous tissue and continues until the graft has been completely replaced. There is no proof, even when a graft has been promptly and snugly fitted into a well vascularized bed, that any significant number of osteocytes survive. Some endosteal cells may persist. The possibility of retaining nutrition of an autogenous bone graft by leaving a muscle pedicle attached has been considered by Hellstadius, who in 1942 summarized the literature in an excellent article and reported a series of experiments in rabbits. He concluded that muscle-pedicled autogenous bone grafts in rabbits offered no advantages over free grafts. However, he described lacunae containing well stained bone cells in the outer one-quarter of the cortex of a skin-pedicled graft from the radial diaphysis and, in one case of a pedicled graft from the greater trochanter, a majority of living bone cells. In the latter instance, the specimen was removed after six days, and Hellstadius considered that delayed autolysis might explain its apparent survival. Although muscle-pedicled bone-graft operations on human subjects have been devised, adequate proof of the superiority of such a graft has never been established.

Codivilla transplanted the axillary part of the scapula with the attached teres minor and teres major to an area of non-union of the adjacent humerus. Cunéo and Block employed a sliding graft for non-union of the femur, transposing the graft from its origin proximally to the region to be covered, with a muscular flap remaining attached. Hahn and Huntington shifted an entire segment of the fibula to replace a large defect in the tibia by transecting it proximally and distally, leaving its muscular attachments. Haas performed an extra-articular arthrodesis of the hip with the aid of a graft from the trochanter which was shifted over the joint with the glutaeus medius still attached. Reichel performed a more complicated procedure when he took a graft with a pedicle of skin and derma from the inner surface of the tibia to the opposite tibia; the patient's legs were crossed and encased in plaster until the pedicle was ready to be severed.[4]

More recently, Davis and Taylor have reported favorably on the use of muscle-pedicle bone grafts in an experimental study of both free bone grafts and muscle-pedicle bone grafts in dogs. Attempts at employing muscle-pedicle bone grafts for spine fusions were not too encouraging, but their use in hip fusions has been satisfactory.[2]

TECHNIQUE

Mature or nearly mature rabbits weighing between 2.5 and 3 kilograms were employed. A rectangle of bone, two centimeters in length, one centimeter in width, and of the same depth as the outer table of the iliac bone, was carefully elevated from its bed, the glutaeus muscle remaining attached (Fig. 1). The entire bone graft was surrounded with tantalum foil of .0003-inch thickness, except in the region where the muscle pedicle entered. The muscle pedicle was handled gently. Constriction of the muscle pedicle by the tantalum or undue tension was meticulously avoided. The graft was then replaced in its bed and sutured in place. Twelve such experiments were performed. In nine of these, the graft was fractured before being wrapped in the tantalum foil in order to determine whether

* Read at the Orthopaedic Section, Academy of Medicine, New York, N.Y., March 20, 1953, and at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 24, 1954.

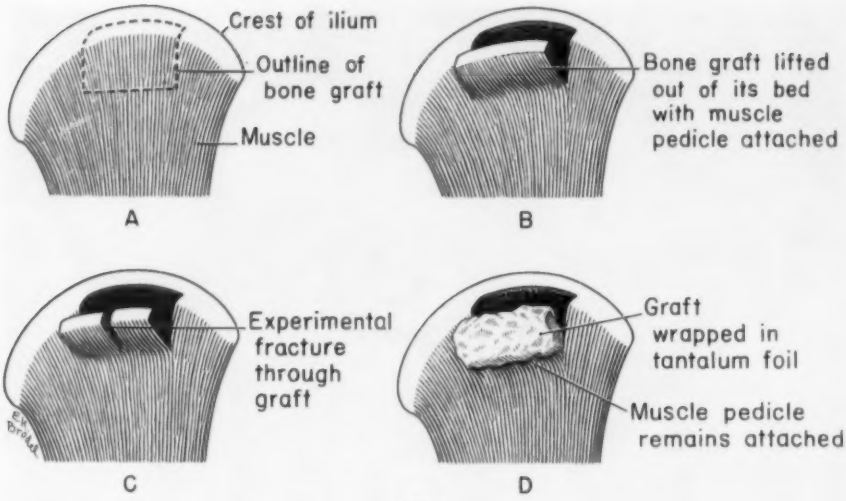

FIG. 1

Diagrammatic presentation of the technique of the experiment. Note in *D* that the muscle pedicle enters the bone through the inferior side of the tantalum.

any reparative osteogenesis would ensue. In three of the experiments, the greater trochanter was used instead of the ilium. A total of fifteen experiments with muscle-pedicle bone grafts were performed.

The control bone grafts were stripped entirely of all muscle, lifted out of their beds,

FIG. 2

Photomicrograph (× 62.5), showing viable muscle pedicle (*S*) attached to underlying periosteum (*P*) and living bone (*L*). Viable marrow (*M*).

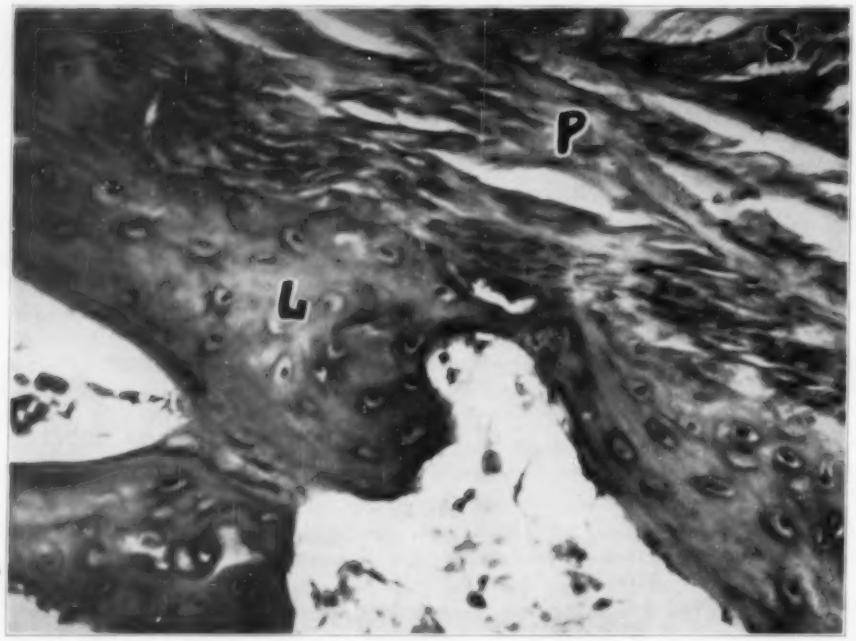

FIG. 3

High-power photomicrograph (× 350) from Fig. 2, demonstrating living bone (*L*) lying under periosteum (*P*). In the corner of the section, one portion of the skeletal muscle pedicle (*S*) can be seen.

and wrapped completely in tantalum foil which was held in place with two encircling cotton threads. The graft was then set back in place and held there by suturing the surrounding soft tissues over it. In three instances, the graft was purposely fractured before being wrapped. In three other instances, one edge of the graft was left uncovered by the tantalum over an area comparable in size and location to the area to which the muscle pedicle remained attached in the other experiments. The grafts were fractured, wrapped, replaced in the original bed, and sutured in position. The purpose of this was to ascertain whether or not nutrition sufficient to keep any of the graft viable could enter through this portion of bone exposed to the surrounding soft tissues.

Immediately after the operations, 300,000 units of procaine penicillin was administered by intramuscular injections. Most of the rabbits were sacrificed twenty-nine to thirty-one days after the experiment. Three of the animals were sacrificed at thirty-eight days. Normal iliac and trochanteric bone was removed from two rabbits and used as a basis of comparison.

RESULTS

Group I: Muscle-Pedicle Autogenous Bone Grafts

In eleven of fifteen experiments, the bone attached to the muscle pedicle demonstrated retained viability varying between one-seventh and nine-tenths of the thickness of the graft (Figs. 2 and 3). Careful differentiation was made in our microscopic studies between new-bone formation and bone with retained viability. Contiguous with the muscle pedicle, viable bone extended for a variable depth, while the bone distal to the pedicle was dead. Of the fifteen experiments, six showed more than half of the original living bone, five less than half, and four disclosed that all of the original bone graft had become necrotic. Analysis of these four experiments demonstrated that the necrotic bone

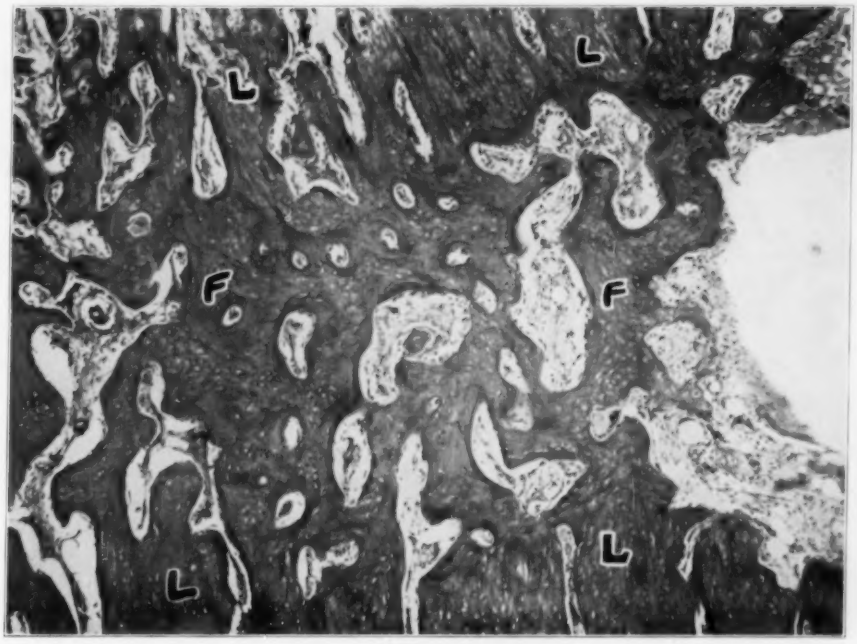

FIG. 4

Healed fracture (*F*) in center of viable bone (*L*) in a muscle-pedicle experiment (× 62.5).

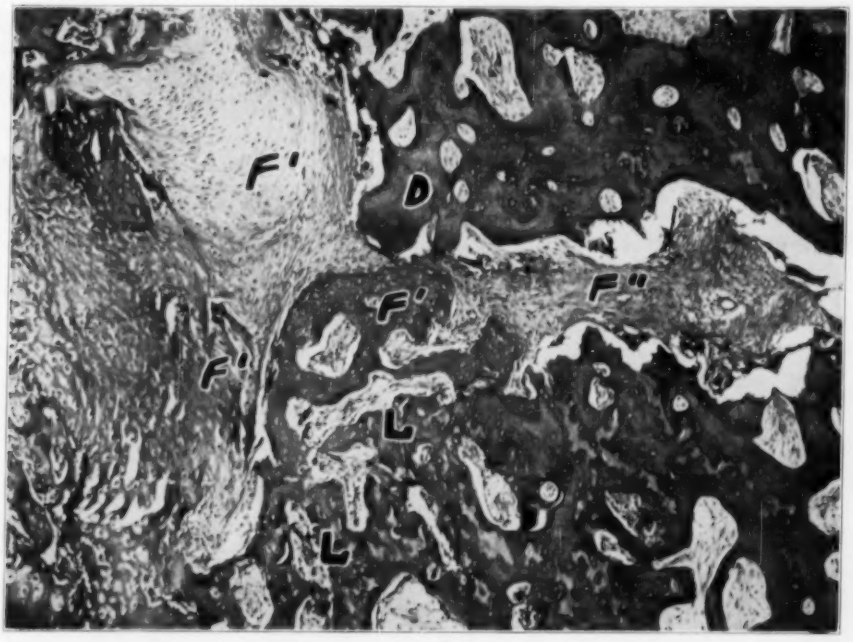

FIG. 5

Partially healed fracture in muscle-pedicle experiment. Note tendency of fracture to heal at *F'* where it is adjacent to living bone (*L*). In the deeper area the fracture is not healed but shows fibrous-tissue reaction (*F''*) surrounded by dead bone (*D*) (× 62.5).

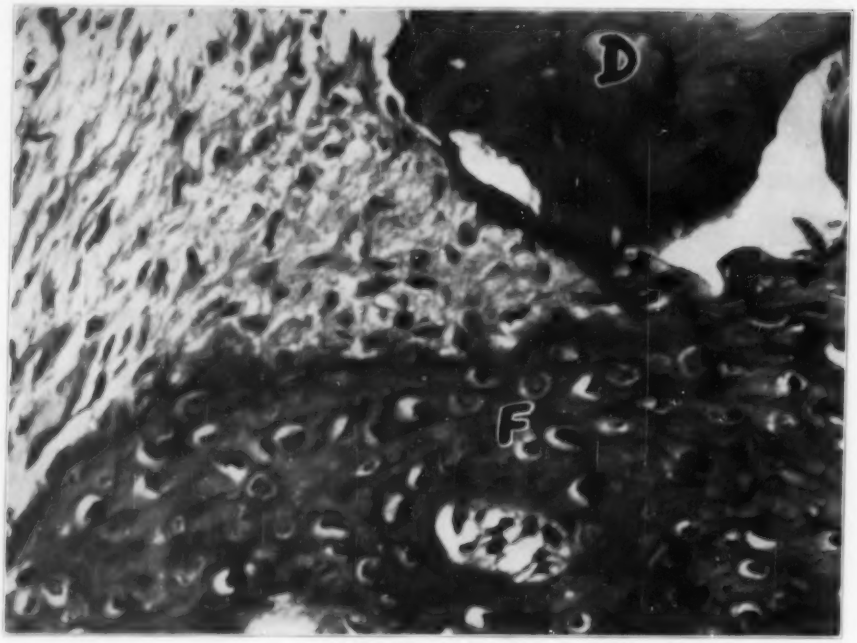

FIG. 6

High-power photomicrograph (× 350) from Fig. 5, showing reparative osteogenesis of the fracture (*F*) adjacent to dead bone (*D*).

was associated with muscle pedicles which were largely necrotic with some fibrous-tissue replacement. Obviously, with the sole remaining avenue of nutrition impaired, the grafts underwent complete death.

In nine of the fifteen experiments, fractures were made across the bone graft. Six of these revealed evidence of reparative osteogenesis in the form of either fracture healing or reactive new-bone formation (Figs. 4, 5, and 6). In one case, the fracture could not be identified grossly or microscopically. In two cases, there was no indication of reparative osteogenesis. This occurred in two of the four experiments mentioned in which the muscle pedicles had become necrotic and total death of the graft had ensued. Thus, where there was some viable bone, the fractures showed some reparative osteogenesis and, in the two cases revealing completely dead bone, there was no evidence of fracture healing. At the junction of viable and necrotic bone, the reactive new-bone formation was quite evident, appearing to arise from the endosteum (Figs. 7, 8, 9, and 10). The marrow was frequently preserved in the region of living bone connected with the muscle pedicle and gradually became fibrous in the more distal regions.

Group II: Controls—Autogenous Bone Grafts Completely Stripped of All Muscles

There were thirteen experiments on various types of controls. In four experiments, the bone was entirely stripped of muscle, completely surrounded with tantalum foil, and then sutured back in place; the graft became totally necrotic. In three experiments, the grafts were prepared in the same way but were fractured; when examined, they revealed completely dead bone and no evidence of healing of the fractures (Fig. 11). Three grafts were stripped of muscle and fractured as in the preceding group but, in the tantalum-foil wrapping, one edge was left uncovered and was thus exposed to the surrounding soft tissues. These grafts were found to be completely dead and presented no evi-

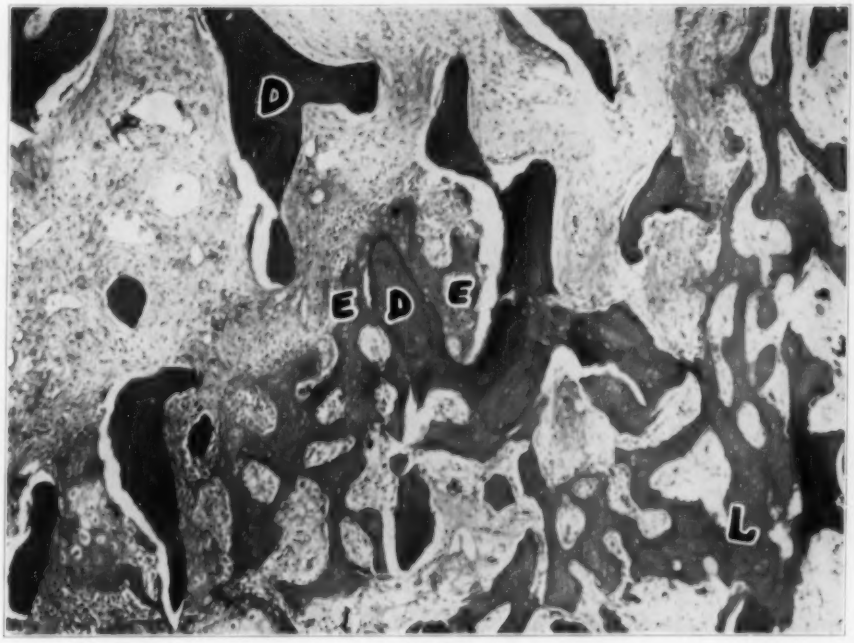

FIG. 7

Reparative osteogenesis (*E*) in the form of endosteal new-bone formation at junction of viable bone (*L*) and dead bone (*D*) in a muscle-pedicle experiment (× 62.5).

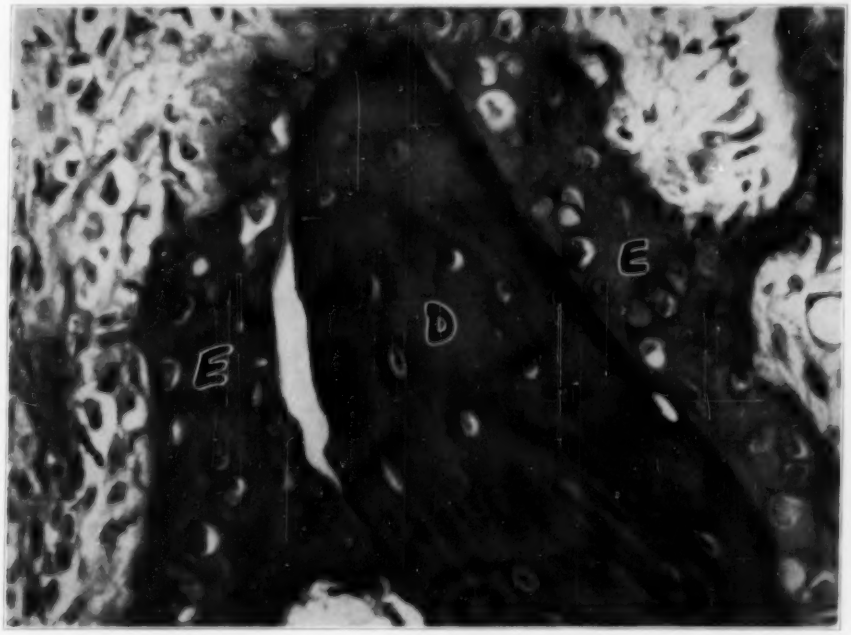

FIG. 8

High-power photomicrograph (× 350) from Fig. 7, showing endosteal new-bone formation (*E*) surrounding dead bone (*D*).

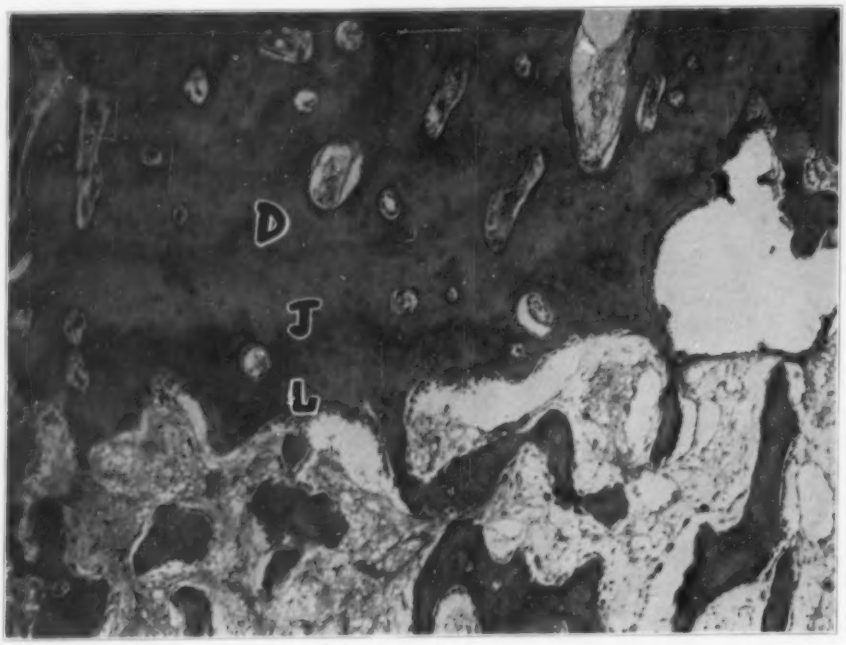

FIG. 9

Muscle-pedicle experiment showing junction (*J*) of viable bone (*L*) with dead bone (*D*) (× 62.5).

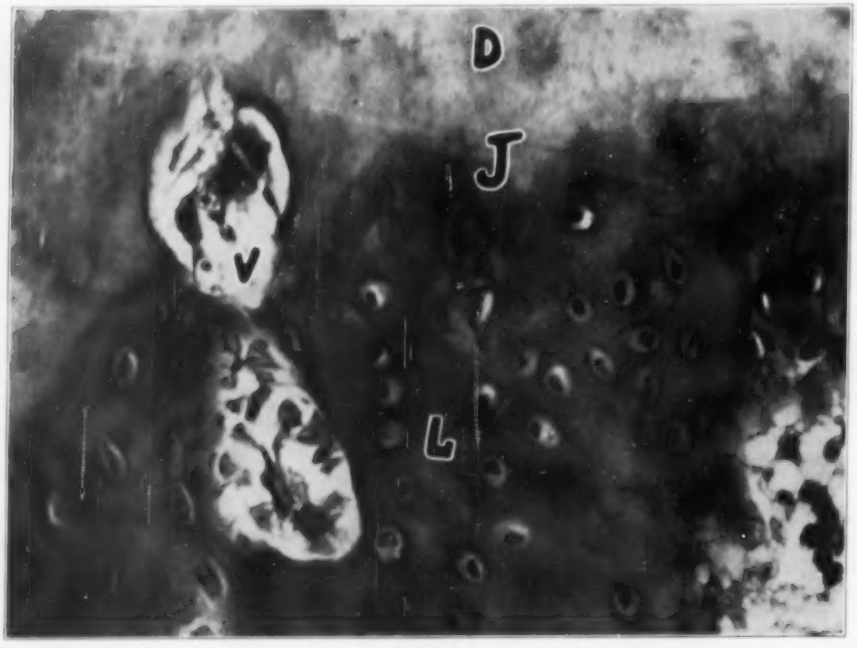

FIG. 10

High-power photomicrograph (× 350) from Fig. 9, showing junction (*J*) of viable bone (*L*) and dead bone (*D*). Note vascular channel (*V*).

FIG. 11

High-power photomicrograph (× 350), showing unhealed fracture (*F*) across bone graft completely stripped of all muscle. Note dead bone (*D*) on both sides of the fracture.

dence of reactive osteogenesis. In three experiments, the grafts were not covered with tantalum foil but were replaced immediately in the original bed without being fractured and were sutured in position. Two of these disclosed that the original graft had completely died, but that reactive osteogenesis was in progress. In the remaining experiment, the graft was so completely fused to the host bed that no line of demarcation could be seen. No microscopic studies were made of this specimen.

In three additional experiments, the bone graft slipped out of the tantalum, thus spoiling the results. In one of these, the graft had reattached solidly to the host bone. These are not included in the thirteen experiments reported above.

COMMENT

Our experiments differed from those of Hellstadius and Davis and Taylor, inasmuch as we employed tantalum foil to block off nutrition from the host bed. It enabled us to isolate a muscle pedicle at one side of a rectangular autogenous bone graft and to test under a controlled situation the efficacy of such a retained blood supply in maintaining the viability of a graft. These preliminary experiments indicated that a portion of the bone graft can be kept viable because of the undisturbed nutritional intake through the muscle pedicle. The deeper regions of the bone graft, distal to the muscle pedicle, became necrotic, indicating that the muscle pedicle can at best only preserve viability of bone for a limited depth. This is consistent with the findings of Johnson, who, in his excellent article on the blood supply of long bones, concluded that the periosteal system does not normally supply more than the outer half or less of the cortex. We could not expect any more of the bone to remain alive with our technique than normally occurs in nature. In eleven of fifteen experiments, bone nourished periosteally through the muscle pedicle could be kept viable. Additional dynamic proof of this viability was gained by

evidence of reactive osteogenesis at the junction of living and dead bone, and also by the fact that in these experiments some of the fractured grafts actually showed healing.

An estimate of the proportion of viable bone in the grafts cannot be made for the series, since our sections were not cut in any standard fashion. A section taken at one angle might show less of the living bone than one taken at another angle. However, between one-seventh and nine-tenths of the bone seen on our sections remained viable. In the four of the fifteen muscle-pedicle bone-graft experiments which revealed entirely dead bone, the muscle pedicles themselves were necrotic.

In the attempt to keep bone viable by way of a muscle pedicle, it is mandatory not only that the graft be taken from an area where muscle is generously attached, but also that the viability of the muscle pedicle be maintained. The persistence of a blood supply entering bone through the pedicle offers the possible advantage of pedicled grafts over free grafts. Hellstadius employed the diaphysis of the radius of rabbits in many of his experiments and found that most of the graft died. The diaphysis of the radius is not the most ideal location for a muscle pedicle. In one of his experiments using the greater trochanter with glutaeus medius attached, he reported that most of the bone survived. Of interest in this respect is the well known clinical observation as to the frequency of delayed union and non-union of fractures in certain regions of the body, particularly in the lower third of the tibia. In this location, the long muscles of the extremity have become largely tendinous and the degree of muscular attachment is markedly diminished in comparison with the upper third of the tibia; in the latter location non-union is rare.

Lexer's injection studies on cadavera demonstrated well the distribution of the blood vessels in the bones themselves. Johnson's classical experiments on dogs shed much light on the distribution of the metaphyseal, periosteal, and nutrient-artery blood supplies to long bones. However, further anatomical investigations correlating the vascular supply of bone, as brought to it through the muscular attachments to the periosteum, would be extremely valuable, especially in reference to the iliac bone.

Our experiments have shown that bone attached to the muscle pedicle can be kept viable and that the deeper bone becomes necrotic. We trust that further pursuit of this investigation will answer the question of how valuable the segment of retained viable bone is in terms of the rapidity of incorporation of the bone graft and what possible advantages, if any, the muscle-pedicle bone graft may have over free grafts. Bone appears doomed to death once the blood supply is momentarily cut off, and reactive new-bone formation is required for regeneration. Endosteal new-bone formation was quite apparent in our slides; this is interesting in reference to the fundamental problem as to whether or not endosteal cells can actually remain viable while the osteocytes have undergone necrosis.[1]

CONCLUSIONS

1. A muscle pedicle permitted to remain attached to autogenous bone grafts in rabbits was effective in retaining viability of the contiguous bone.

2. The deeper areas of pedicled bone grafts, remote from the muscle pedicles, did not remain viable.

3. Fractures through the experimental bone grafts with muscle pedicles showed evidence of reparative osteogenesis in the region of the viable bone.

4. Control experiments without muscle pedicles revealed necrosis of the bone grafts.

5. Fractures of the control bone grafts showed no evidence of reparative osteogenesis.

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DISCUSSION

Dr. Joe B. Davis, Portland, Oregon: It has been a privilege to review and hear the presentation of this manuscript. This appears to be an example of splendid experimental work. To the best of my knowledge, utilization of tantalum foil to isolate a muscle-pedicle graft is an original technique in bone-graft research.

When Dr. Taylor and I first became interested in this subject, we established proof of maintenance of viability in cancellous bone by means of pedicles of muscle-belly origin. My recent experiments on dogs, similar to those presented here today, reveal essentially the same results as those presented by Dr. Hartley and Dr. Silver. From the results of the experiments which have now been presented, it becomes evident that cancellous bone can be transmitted in a viable state because of the muscle-belly pedicle. Furthermore, healing of fractures will occur in such muscle-pedicle bone grafts.

For the past three or four years, I have been using this principle of bone-grafting in various parts of the body and, of course, this has been done by numerous other workers. The anterior crest of the ilium lends itself well to transplantation to the hip joint, the tensor fasciae latae and the anterior portion of the glutaeus medius being used as the muscle pedicles. The posterior crest of the ilium may be used with the glutaeus maximus as the pedicle for areas around the sacro-iliac joint. My attempts to use the posterior crest of the ilium with the sacrospinalis as the pedicle for transfer to the spinous process in the lumbosacral area were thwarted by technical difficulties that were insurmountable. The deltoid muscle serves as a fine pedicle for transplanation of the acromion process to the shoulder. Recently I have been using the anterior lateral surface of the calcaneus with the short toe extensors as the pedicle in the transfer of bone for triple arthrodesis of the foot.

These bone-graft operations have been easily accomplished and have not presented any particular technical difficulties, with the exception of the unsuccessful attempts in the lumbosacral area of the spine. The shoulder arthrodesis is facilitated by this technique as the exposure is accomplished easily, bleeding is minimal, and retraction is simplified.

I consider that this paper represents a sound piece of experimental work with valuable clinical implications. I would encourage all of you to utilize this sound principle of transplanation surgery whenever an occasion arises in which it seems applicable.

Dr. Paul R. Lipscomb, M.D., Rochester, Minnesota: Dr. Hartley and Dr. Silver have demonstrated a simple but efficient method of isolating a muscle-pedicle bone graft from influencing factors present in the recipient bed. In all previous experiments with this and many other types of bone grafts, it has been difficult if not impossible to ascertain the role of the graft in the production of new bone.

Even in an experiment as carefully controlled as was this one, it is impossible, after a few weeks, to distinguish new bone from pre-existing bone. As an example, in one instance of a fracture through a muscle-pedicle graft in a rabbit, the authors were unable to identify the fracture grossly or microscopically after terminus, sometime between twenty-nine and thirty-eight days after the experiment. Perhaps this animal was one of the nearly mature, rather than mature, rabbits mentioned; if such was the case, more rapid and better healing of the fracture might be expected. A few weeks' difference in age in rabbits may be equivalent to a few years in human beings.

A number of us, including myself, when performing experiments connected with osteogenesis, have made the mistake of neglecting to recognize these most fundamental facts. I should like to emphasize the importance in all laboratory experiments concerning osteogenesis of comparing results only in animals of the same age, size, strain, environmental influences, and preferably also of the same sex. Otherwise, the data accumulated are open to question from the beginning.

Although it is easy to distinguish frankly necrotic bone and young proliferating bone histologically, it is often impossible to examine a section of mature bone under the microscope and to determine whether that bone was living or dead at the time the specimen was placed in a fixative solution. The fact that lacunae of mature bone contain cells is no assurance that those cells were living. Conversely, the fact that lacunae contain cells which appear shriveled is no assurance that those cells were dead. The real criterion of whether or not an osteocyte is alive lies in its ability to revert to an osteoblast and multiply when stimulated by trauma or disease.

(*Continued on page 840*)

A METHOD OF TREATMENT OF FRACTURE-DISLOCATIONS OF THE FIRST METACARPAL BONE *†

BY COMMANDER HOWELL E. WIGGINS AND COMMANDER WARNER D. BUNDENS, JR.,
Medical Corps, United States Navy
AND LIEUTENANT (J.G.) BYRON J. PARK, *Medical Corps, United States Navy Reserve*

Any discussion of fracture-dislocation of the first metacarpal would be incomplete without giving credit to Edward Halloran Bennett, who in 1881, before the Dublin Pathological Society, exhibited a series of fractures of the metacarpal bones, five of which involved the first metacarpal. It was Bennett's impression that fractures of the first metacarpal should not be considered trivial injuries for, although they united readily without apparent gross deformity, he noted that in most cases the thumb remained lame and useless for many months, and a weak grasp persisted permanently.

The authors concur with the views expressed by Bennett concerning the importance of these fractures of the thumb. However, there are opinions expressed in the literature which are in disagreement, as evidenced by the report of Blum. He stated that the enarthrodial or ball-and-socket type of joint which forms as the result of a healed, unreduced Bennett fracture may well represent a more desirable end result than a perfect restoration of the original, structurally weak, diarthrodial joint, which may again be subject to the same kind of trauma as that which caused the original injury.

Because, in the literature, there is much confusion of terms in the descriptions of fractures of the first metacarpal, a classification of these fractures as developed by McNealy and Lichtenstein is given here:

"I. At the base.
  a. Intra-articular.
    1. Bennett type
    2. Rolando type
  b. Extra-articular.
    1. Transverse
    2. Oblique
    3. Complicated
"II. The shaft.
    1. Transverse
    2. Oblique
    3. Longitudinal
"III. The head.
    1. Transverse

"Winterstein cites some interesting statistics on the relative distribution of fracture sites in 200 cases of fracture of the first metacarpal."

They are as follows:

TYPES OF FRACTURES IN 200 CASES OF FRACTURE OF THE FIRST METACARPAL

Fracture	*Percentage of Series*
I. At the base	
A. Intra-articular	
1. Bennett type	29.0
2. Rolando type	7.0
B. Extra-articular	
1. Oblique	10.0

* The opinions or assertions contained herein are the private ones of the writers and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

† Read at the Annual Meeting of the Western Orthopedic Association at Sun Valley, Idaho, October 5, 1953.

Fracture	*Percentage of Series*	
2. Transverse	25.0	
3. Complicated	9.0	
Total		80.0 per cent.
II. The shaft		
A. Oblique	1.5	
B. Transverse	2.0	
C. Longitudinal	2.0	
Total		5.5 per cent.
III. The head		
A. Transverse	2.5	
B. Capsular evulsion	5.0	
Total		7.5 per cent.
IV. All others, including epiphyseal injuries, crush injuries, and combinations of the above.	7.0	7.0 per cent.
Grand Total		100.0 per cent.
Right hand	60.0 per cent.	
Males	97.5 per cent.	

The first metacarpal-multangular articulation is a saddle-shaped joint which allows an extreme range of motion but is at the same time structurally weak. The joint is most stable in the extended and abducted position, since under these circumstances any force applied to the thumb is transmitted along the longitudinal axis of the shaft to the center of the greater multangular. When the metacarpal is flexed and adducted, however, force directed along the shaft is transmitted more to the "hook", or palmar articular process. A shearing force results, which causes the fracture. The hook remains articulated with the greater multangular, while the dorsal portion subluxates posteriorly or posterolaterally.

The ligamentous damage in these fractures is usually not so severe as one would expect. Both dorsal and volar ligaments are initially foreshortened by the injury, while the short intermetacarpal ligament between the first and second metacarpals is undisturbed, since it remains attached to the undisplaced or palmar articular fragment.

In describing the mechanism of injury in fractures involving the proximal joint, Rolando stated that the dorsal articular process presents much greater resistance to external violence than the palmar articular process, especially when the injuring force acts in the direction of the longitudinal axis of the metacarpal. The effect of this violence is to render more acute the angle formed by the palmar articular process with the palmar surface of the metacarpal, with the result that an oblique fracture occurs at the base of the process, the fracture line extending from a point near the center of the articular surface to the palmar surface of the shaft. If violence is very severe, a fracture of the stronger dorsal articular process may result as well. In these cases there is, in effect, a Y fracture comprising three fragments, — the dorsal and palmar portions of the base and the shaft. This is known as the fracture of Rolando. The articular fragment on the palmar surface constantly turns toward the thenar eminence, while the dorsal articular fragment retains its relations with the greater multangular. The diaphyseal fragment may present a dorsal subluxation as in Bennett's fracture or there may be no dislocation.

TREATMENT

Treatment of fracture-dislocations of the first metacarpal has varied widely since the original description by Bennett.

According to James and Gibson, the treatment of Bennett's fracture has included four general methods:

1. Immobilization of the abducted, extended thumb in plaster for three weeks, following which the cast is removed and the thumb is strapped with adhesive for two weeks;

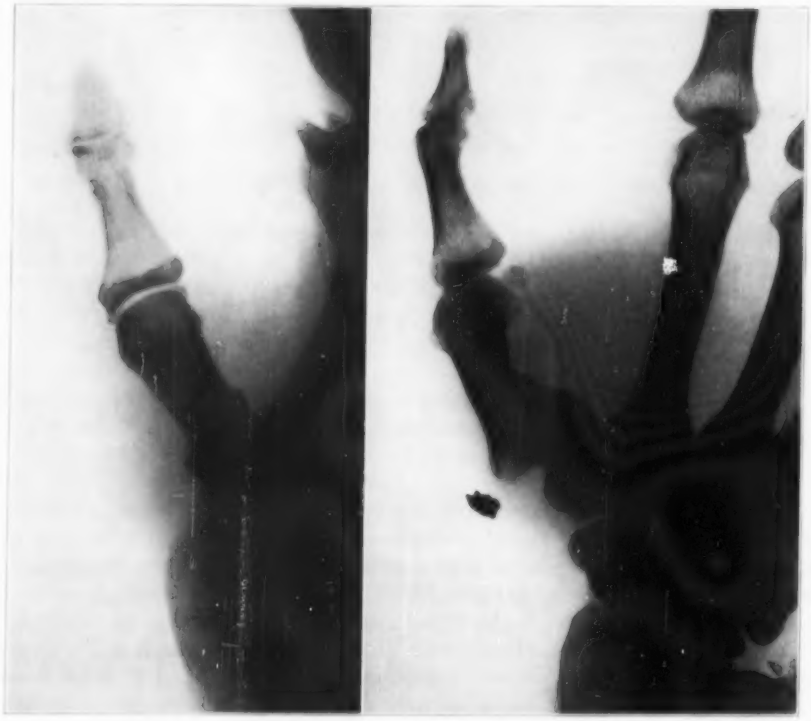

FIG. 1-A
Typical Bennett's fracture. The metallic fragment seen is an artifact.

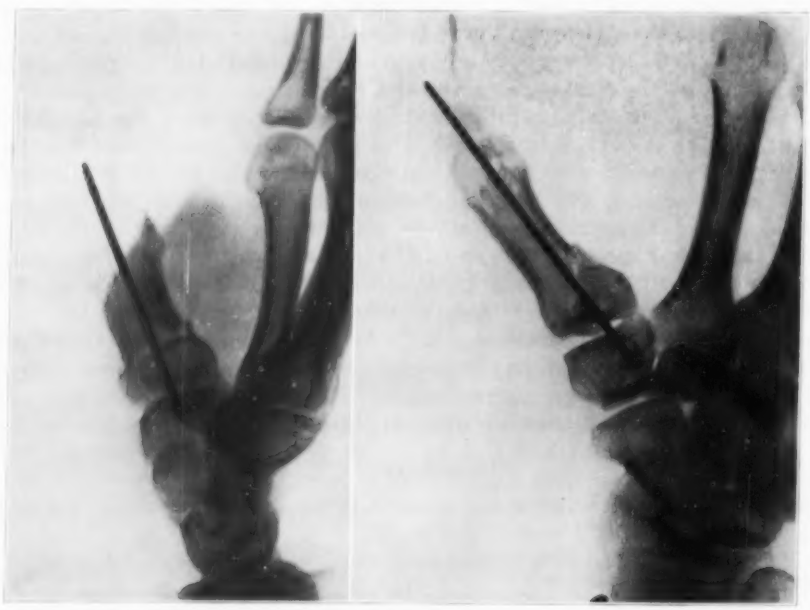

FIG. 1-B
Postreduction roentgenograms with the intramedullary wire *in situ*.

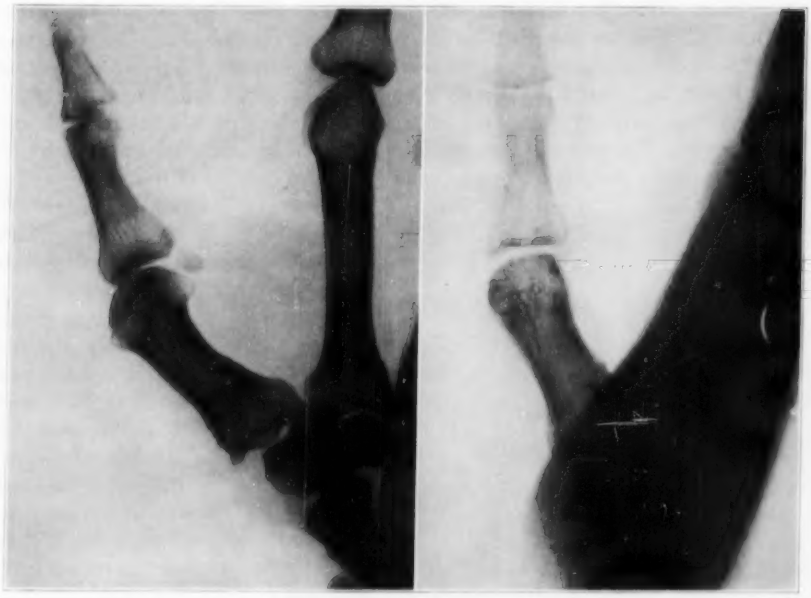

FIG. 1-C

Roentgenographic appearance at the end of the fifth month following the injury.

2. Traction by means of a banjo splint, utilizing pulp traction, adhesive traction, or skeletal traction in which a pin or needle is passed through the nail or terminal phalanx;

3. Fixation with a roller bandage between the thumb and index finger and with the thumb strapped over the bandage by adhesive tape;

4. Immobilization of wrist and forearm with a plaster cast incorporating a small Thomas splint for the thumb, the fracture having been previously reduced by abducting and extending the thumb. A felt pad is held over the fracture by adhesive.

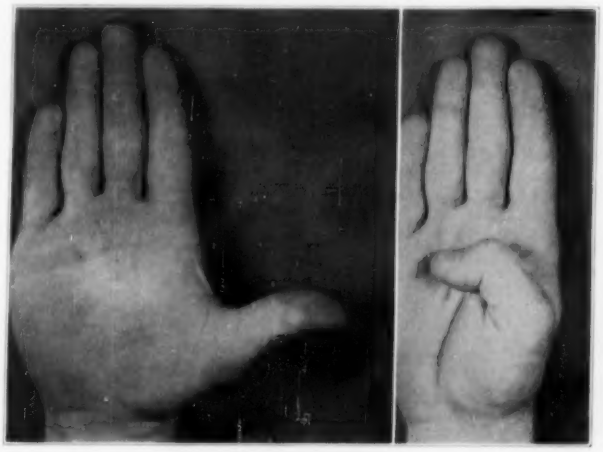

FIG. 1-D

Range of flexion and extension of the involved thumb five months after injury.

Ellis utilized open reduction in all Bennett fractures, reducing the fracture under direct vision and driving two pegs or nails obliquely into the greater multangular in order to form a shelf so that re-dislocation could not occur. Immobilization was continued for six weeks, following which the plaster was removed, and the pegs were taken out at a further minor operation.

Macey and Murray were of the opinion that in most Bennett fractures an open reduction was necessary in order to maintain an adequate reduction and to prevent the develop-

ment of a painful arthritic joint at a later date. They advised fixation of the fragments by means of small pins, as described by Bunnell. Blum, because of his belief that an unhealed Bennett fracture was a more desirable end result than a perfect reposition of the fragment, treated his patients by simple physiotherapy and bandaging.

Since our end results in the treatment of these fractures with skeletal traction were unsatisfactory, because of residual interphalangeal-joint stiffness and the loss of position of fragments, early in 1951 we began using the method of fixation described by Wagner. Although our results with this method were satisfactory, the positioning of the Kirschner wire or wires proved to be rather difficult. Since the method could not be adapted to general use, it was abandoned and a new method was developed.

FIG. 2-A

Oblique basilar fracture with marked instability.

Following a study of the deformity produced by these fractures and the anatomy of the region involved, it was proposed by one of us (W.D.B.) that the reduction might be maintained by the use of intramedullary fixation. A medium-sized Kirschner wire, inserted through the head and passed down the medullary canal, was found to penetrate the very center of the greater

FIG. 2-B

Reveals the alignment following intramedullary wire fixation through plaster.

FIG. 2-C

Reveals the condition of the metacarpal at the end of the fourth week following the injury.

multangular, provided that the metacarpal was held in extension and abduction during the insertion of the wire and that the fracture had been properly reduced. With this wire in place, the reduction was maintained in a very stable fashion.

The one objection to this method was that the wire penetrated the extensor apparatus of the metacarpal-phalangeal articulation. In the first patient treated in this manner, the thumb was not immobilized and slight skin irritation developed about the pin. We have since used a light plaster dressing in such cases and have had no further difficulty.

FIG. 2-D

A composite view of the right hand showing the range of motion of the right thumb at the sixth month following the injury.

TECHNIQUE

With the patient under adequate anaesthesia, and with sterile technique at all times, an assistant flexes the first metacarpal-phalangeal joint to approximately 110 degrees and maintains gentle traction along the axis of the metacarpal, while holding it in the abducted and slightly extended position. This manoeuvre usually results in an anatomical reduction of the typical Bennett fracture, but direct pressure over the dorsal or dorsolateral surface of the base of the first metacarpal may occasionally be necessary as well, in order to secure satisfactory reduction. The position is checked by fluoroscopy, and a medium-sized Kirschner wire is then directed into the posterior aspect of the center of the head. Once this wire has been started correctly, it traverses the medul-

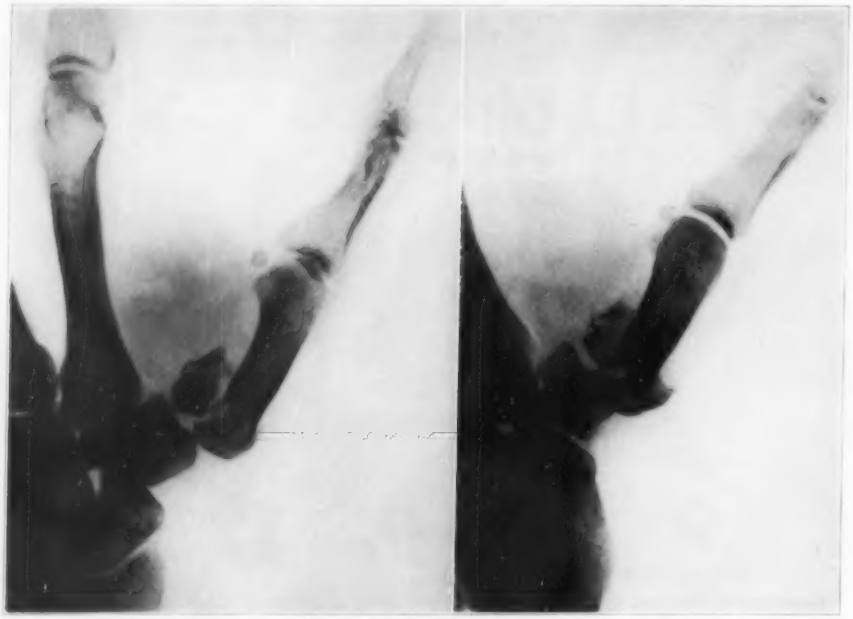

FIG. 3-A
Severe Rolando-type fracture-dislocation.

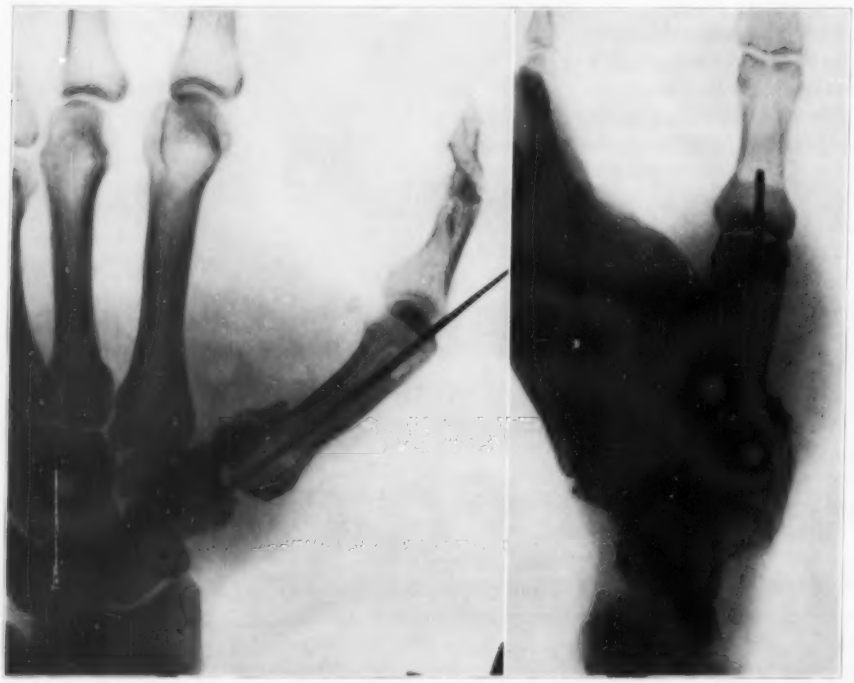

FIG. 3-B
Reduction of fracture with intramedullary wire *in situ*.

lary canal without difficulty and enters the center of the greater multangular. Once more a fluoroscopic check is made to gauge the penetration of the wire into the greater multangular. The wire is then cut off, approximately one centimeter distal to the skin; a small dressing is applied, followed by a glove-type plaster-of-Paris cast which includes the entire thumb but permits full motion of the remaining four digits.

In several of the early cases, the intramedullary wire was found to pass posteriorly or laterally to the greater multangular on initial insertion. This was found to be due to one of the following:

1. Incomplete reduction;
2. Not keeping the metacarpal in wide abduction;
3. Not maintaining direct pressure on the base;
4. Starting the wire too far laterally on the head, thus allowing it to strike and be deflected by the opposite cortex of the metacarpal.

Threaded wires have been used in several cases, but they appear to be beneficial only in the Rolando or severely comminuted fractures, where they may prevent some foreshortening.

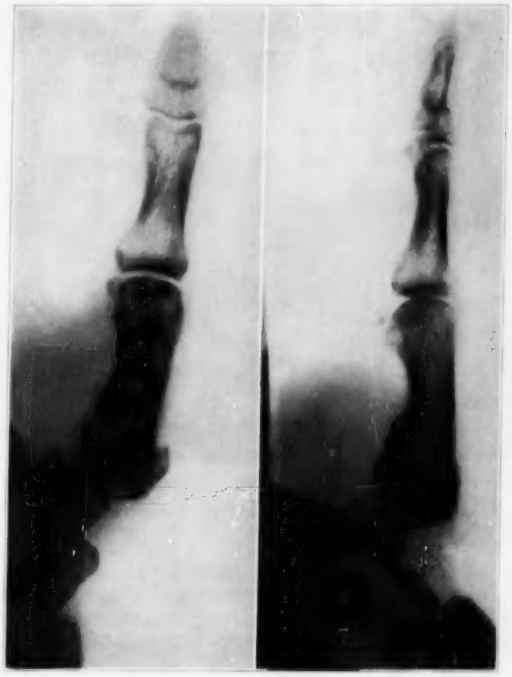

FIG. 3-C

The alignment and healing of the fragments at the end of the third month.

FIG. 3-D

Two months after injury, range of extension of the left thumb compared with a normal right thumb.

FIG. 3-E

Range of flexion of the left thumb compared with normal right thumb, two months after injury.

Immobilization in plaster is continued for four weeks, following which the intramedullary wire is removed without anaesthesia, and active use of the thumb is begun.

CASE 1: T. M. F., a forty-year-old Civil Service employee, injured his right thumb on January 30, 1952. A roentgenogram (Fig. 1-A) revealed a typical Bennett fracture. On February 4, 1952, under brachial-block anaesthesia, reduction of the fracture-dislocation was accomplished without difficulty, and satisfactory fixation was achieved by means of an intramedullary wire. Five months following the injury there was a normal range of motion, and the patient was asymptomatic.

CASE 2: J. L. M., a Navy enlisted man, twenty-three years old, injured his right thumb on June 28, 1952. A roentgenogram revealed an oblique fracture of the base of the first metacarpal bone. On June 29, 1952, under brachial-block anaesthesia, the fracture was reduced and fixed by an intramedullary Kirschner wire. Figure 2-B is the postoperative roentgenogram, while Figure 2-C shows the result four weeks after injury. Six months after injury, the patient had no symptoms and had a normal range of motion as shown in Figure 2-D.

CASE 3: M. G., a Civil Service employee, thirty-nine years old, received a severe injury to the left thumb on March 23, 1953, resulting in a closed fracture of the distal phalanx and a comminuted fracture-dislocation, of the Rolando type, involving the base of the first metacarpal (Fig. 3-A). Figure 3-B is the roentgenogram taken after reduction and intramedullary fixation. A threaded Kirschner wire was used in this case in an attempt to maintain the length. At the end of the second month, the patient had no symptoms referable to the thumb and there was a good range of motion. He returned to his occupation as a boilermaker. On examination six months after the injury, the proximal end of the first metacarpal was found to be still somewhat enlarged. There was no instability, and the patient felt that his left hand was as good as his right.

A total of twenty-eight cases of fracture or fracture-dislocation of the first metacarpal have been treated by intramedullary fixation, the technique being used as described. The location of these fractures is given below:

Type of Fracture	*No. of Cases*
I. At the base	
A. Intra-articular	
1. Bennett	14
2. Rolando	2
B. Extra-articular	
1. Oblique	5
2. Transverse	4
II. The shaft	
A. Oblique	2
B. Transverse	1

The results of this method of treatment have been extremely gratifying in all cases. Anatomical reduction was achieved and maintained in all the cases except the two Rolando-type fractures. In the latter two cases, the base of the metacarpal remained

somewhat widened and the metacarpal was slightly foreshortened. However, bony union occurred with the shaft centered over the greater multangular, and the functional result was excellent. There were no cases of residual instability, subluxation, non-union, or significant degree of loss of joint motion. Except for the first case in which there was a slight irritation about the pin, no infections have been encountered. A light plaster dressing has since been applied in all cases. The most severe fracture encountered in the entire series was that presented as Case 3.

The method of treatment outlined is a simple procedure and can be performed with equipment available to every orthopaedist. It gives stable fixation without the dangers of pressure sores or residual joint stiffness in poor functional position. Intramedullary fixation of these fractures permits splinting of the thumb in the position of function.

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DISCUSSION

Fracture of the Carpal Navicular Bone

(*Continued from page 774*)

fixation is good for fractures of the neck of the femur, on theoretical grounds it should be better for fractures of the carpal navicular, as the wrist is a non-weight-bearing joint.

Dr. McLaughlin stated that none of the proximal fragments bled, but that all of the distal fragments did. From this observation it would seem probable that the proximal fragments in the majority of fractures of the carpal navicular require revascularization. Revascularization takes place gradually from the distal fragment into the proximal fragment. Unfortunately, in fractures of the neck of the femur and fractures of the talus, that portion of the bone which requires revascularization most (the subchondral weight-bearing area) is revascularized last. In the carpal navicular, on the other hand, the area to be revascularized is smaller, and actually revascularization is seen in many of these fractures.

The saving of time by internal fixation, compared to the long period required for cast immobilization, makes this an intriguing idea. I have enjoyed hearing the paper and the privilege of discussing it.

GRIP TEST

The Use of a Dynamometer with Adjustable Handle Spacings *

BY CHARLES O. BECHTOL, M.D., OAKLAND, CALIFORNIA

Grip, or "large grasp," is one of the hand functions which should be evaluated in any hand disability. This paper presents observations on the use of a grip dynamometer with adjustable handle spacings. The adjustable handle spacings allow a much more accurate evaluation of the force of the grip of the injured hand.

BIOMECHANICS OF THE HAND

The biomechanics of the hand has been carefully studied as a preliminary to the design of artificial limbs. This work has been carried out in the Engineering Department at the University of California, Los Angeles, by Dr. Craig L. Taylor, Ph.D., under the auspices of the Advisory Committee on Artificial Limbs of the National Research Council. Three types of prehension for smaller objects have been demonstrated. They are: finger-tip pinch, lateral pinch, and fingernail pinch.

Finger-tip pinch is the one most commonly used. An object is picked up between the pad of the thumb and the pads of the index and middle fingers. Lateral pinch produces slightly more force and is used, for example, to extract a magazine which is jammed tightly into a rack. It is accomplished by bringing the pad of the thumb against the lateral side of the index finger at the distal interphalangeal joint. The index finger is supported by the three adjoining fingers.

FIG. 1

Fingernail prehension is used

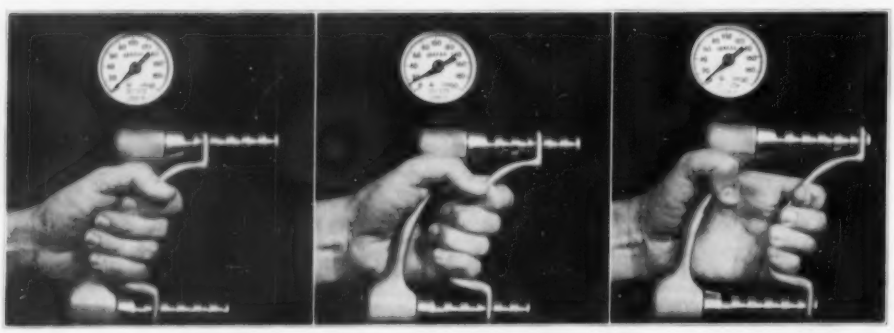

FIG. 2

Fig. 1: Original dynamometer, based on the cable tensiometer, allows handle spacings to be adjusted. (Reproduced by permission from *Instructional Course Lectures* of The American Academy of Orthopaedic Surgeons, Vol. X, p. 245. Ann Arbor, J. W. Edwards, 1953.)

Fig. 2: Hydraulic dynamometer, using metal sylphons. This type is now in use. The handle is shown at the 1-inch, 2-inch, and 3-inch spacings. (Reproduced by permission from *Instructional Course Lectures* of The American Academy of Orthopaedic Surgeons, Vol. X, p. 245. Ann Arbor, J. W. Edwards, 1953.)

* Read at the Ninth Annual Meeting of the American Society for Surgery of the Hand, Chicago, Illinois, January 22, 1954.

FIG. 3

FIG. 4

Fig. 3: The method of testing finger-tip prehension.

Fig. 4: The test for lateral prehension.

Fig. 5: Testing the force of elbow flexion. (A felt or sponge-rubber pad should be placed over the forearm.)

FIG. 5

almost exclusively to pick small objects, such as pins, from a flat surface. It is accomplished by increasing the flexion of the joints of the fingers and the thumb, so that the nails of the thumb and index and middle fingers are brought together.

The use of the hand for grasping larger objects falls into two general categories. The hand may be used as a hook or a snap, and it may be used for large grasp, which will serve to encompass or to hold larger cylindrical, spherical, or irregularly shaped objects. The function of the hand as a hook or a snap is characteristic in the carrying of a suitcase. It is accomplished either by flexion of the fingers so that the four fingers act as a hook, or, commonly, by closing the pad of the thumb over the nails of the index and middle fingers so that the grasping surface is closed and acts as a mechanical snap.

The function of large grasp is carried out by the thumb opposing the four fingers. The object is usually in contact with the entire surface of the thumb, the palm, and the fingers. A characteristic example is picking up a water glass.

DESCRIPTION OF THE MEASURING INSTRUMENTS USED

The two types of dynamometer (Figs. 1 and 2) used in this test were designed to the following criteria:

1. The handle should be adjustable, for spacings of 1, 1.5, 2, 2.5, and 3 inches;
2. The handles should be large and smooth, so that a forceful grip is not painful;
3. The handles should move together less than one-eighth of an inch during the test, so that the test will be isometric.

At the smaller handle spacings, the dynamometer may also be used to test finger-tip pinch (Fig. 3) and lateral pinch (Fig. 4). With the handles spaced three inches apart, the dynamometer may be used to test the force of many other movements. The examiner holds the fixed portion of the handle, and the subject presses against the movable portion of the handle, which has been padded with either sponge rubber or felt (Fig. 5).

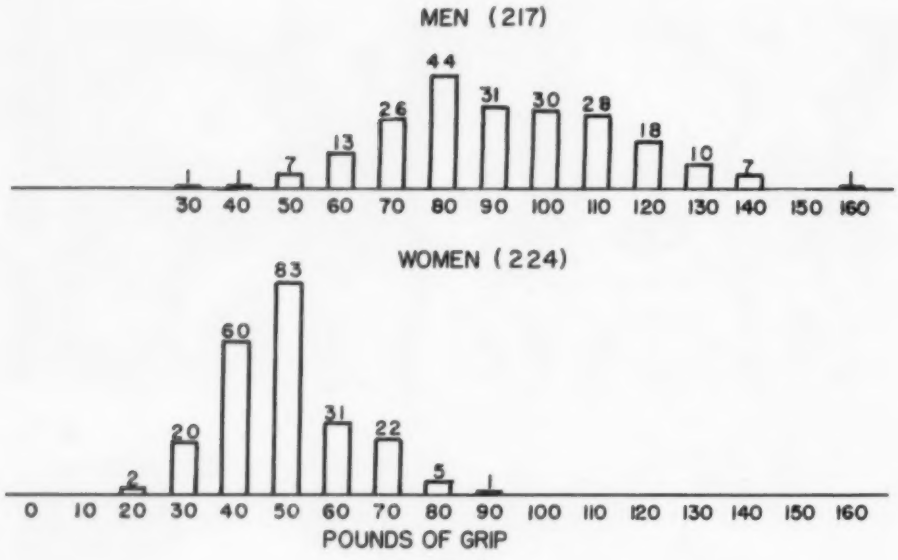

CHART I

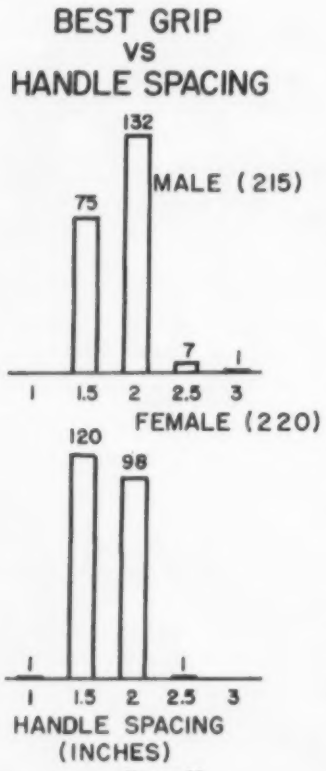

CHART II

TECHNIQUE OF THE TEST

The subject is shown how to grasp the dynamometer and is requested to grasp it with his maximum force. The grip is measured at each of the five handle spacings. The right and left hands are tested alternately, and the force of each test is recorded immediately, thus pacing the test at such a rate that fatigue will not be a factor.

THE FORCE OF NORMAL GRASP

As in any measuring of muscular force, there is a wide variation between the weakest and the strongest recorded. The results recorded here are from an unselected group of patients seen in the office. In no patient, as far as could be determined from history and physical examination, was there any abnormality in the hand function. Patients giving evidence of failure to cooperate in the test were eliminated. Both right and left hands are considered here together; the variations seen in the "major" and "minor" hands will be discussed later. It is obviously impossible in a study such as this to define the limits of a normal grip. These figures, presented merely as a frame of reference, indicate the extreme variations which will be found in the course of ordinary grip-testing (Chart I).

The majority of male grips were recorded between 60 and 130 pounds. The men in this series formed two general groups,—the sedentary workers with a grip of seventy or eighty pounds, and the workers who do more active labor (particularly in occupations requiring a forceful grasp),

most of whom presented a grip of 100 or 110 pounds. The results of tests in women are quite different, most of the grips being between thirty and seventy pounds, with the majority recorded at forty or fifty pounds. Most men presented their maximum grip at the 2-inch handle spacing; a considerable number were recorded at the 1.5-inch handle spacing. The situation was reversed in women; the largest number were better at the 1.5-inch handle spacing (Chart II). This probably represents the effect of their smaller hands. Most men's hands, when measured from the flexion crease at the wrist to the tip of the middle finger, were between seven inches and eight and one-quarter inches long. Women's hands, measured similarly, were between six and one-half inches and seven and one-half inches long.

FACTORS INFLUENCING THE GRIP

1. *Hereditary factor:* There is probably a certain maximum for each individual which limits the force he can produce even after prolonged training. It is interesting in this regard to observe the lack of correlation between the appearance of the forearm musculature and the grip recorded. The best grip recorded to date was in a slender subject, six feet, four inches tall, with no history of athletics or activity which would strengthen his grip. His maximum grip was 204 pounds. His arm would be described on observation as slender and non-muscular. In contrast to this, a professional weight lifter presented an extremely powerful and muscular arm and a maximum grip of 120 pounds. He stated that he had never bothered to specifically exercise his grasping power, since his hand could easily hold the largest weight which he could lift with his arm musculature. He demonstrated a very powerful force of hook in his four fingers, 226 pounds. In any normal hand, the hooking power of the four fingers is considerably greater than the grasp.

This leads to two important conclusions about hand function: First, the hand can usually hold any object which the shoulder and arm muscles are powerful enough to lift, and, second, the limiting factor in the force of the grasp is the power of the thumb and the thenar eminence to oppose the more powerful force of the four fingers. The most important muscles in the grip, therefore, are those of the thenar eminence.

2. *Size of the object:* The force of the grasp was usually about 30 per cent. less when grasping the handles at the 1-inch mark than at the 3-inch mark. The maximum force was usually obtained at the 1.5-inch or 2-inch handle spacing.

3. *Results of exercise:* In order to increase the force of the grasp, the activity must specifically require a forceful grip. The mere handling of heavy objects is not sufficient. Men who handle heavy cargo in boxes or sacks, for example, do not usually present a superior grasp. In contrast to this, a worker who uses a pair of pliers or milks cows will develop a very forceful grasp. The increased force of the grip which follows such exercise may persist for a long time, in spite of lack of continued exercises. Many subjects have been tested who milked cows until the age of twelve or sixteen, but had done no similar work for a period of ten or twenty years. These subjects, both men and women, usually presented a superior grip.

4. *Handedness:* The major hand may be as much as 30 per cent. stronger than the minor hand. Most subjects presented a difference of 5 to 10 per cent. A number of cases have been observed in which there was an occupational reversal of handedness, and the minor hand was stronger. This was frequently seen in left-handed subjects, the minor hand being 5 to 10 per cent. stronger than the major hand, and, in one case, the difference in strength was 30 per cent.

5. *Variation during the day:* There may be a variation in the grip of as much as 30 per cent. during the day. The low gripping power occurs in the early morning. The grip reaches its maximum strength between 4:00 and 8:00 in the evening. If the subject is hypoglycaemic just before a meal, the grip may be reduced by 10 per cent.

6. *Variation from day to day:* There is little variation from day to day if the grip is

measured at the same time of day. The usual variation does not exceed 10 per cent. General malaise, such as that associated with a cold, may make the test seem to be a much greater effort; however, it usually does not reduce the force of the grip.

7. *Age:* Nemethi found a comparatively small variation in force of the grip between the ages of eighteen and sixty-five. The best grips were found between the ages of twenty-five and forty. Between eighteen and nineteen, the values were about 10 per cent. lower, and between the ages of fifty and sixty-five, the values were about 15 per cent. lower than in the group between the ages of twenty-five and forty.

8. *The effect of pain:* This is an extremely variable factor and depends largely upon the subject's threshold of pain. Pain in the hand or fingers will, of course, have a greater effect in reducing the grip than pain in the forearm. Pain above the elbow has little effect upon the force of the grip.

TESTING THE INJURED HAND

Following the injury, there may be a limited motion of the fingers which will restrict the grasp to objects of large or small size. By the use of a device with adjustable handle spacings, this limitation of grasp can be clearly shown, and it is frequently found that the subject's grasp within certain limits is within the range of normal. For example, a railway brakeman was unable to grasp objects larger than two inches with his right hand and one and one-half inches with his left hand, because of an old bilateral Dupuytren's contracture of many years' duration. Within the limits of his grasp, however, the force of the grip was normal. This man stated that he had noted no difficulties in his occupation as a railway brakeman for a period of seventeen years. He had chosen the correct occupation for his disability, since the rungs of the ladders and the brake wheel of the standard freight car are three-quarters of an inch in diameter.

FAILURE TO EXERT FULL EFFORT DURING A GRIP TEST

Objective evidence can be obtained if the subject fails to carry out the test with his full effort. The basis for this portion of the test is as follows: When the subject exerts his full effort, repeated tests can be carried out and the values will vary less than 20 per cent. and usually less than 10 per cent. If the subject, however, attempts to grip with less than his maximum effort, he will be unable to duplicate this partial effort when the test is repeated after an interval of a few minutes. The discrepancy will usually be greater than 20 per cent. and may frequently be as great as 100 per cent. or more. If the examiner suspects that the subject may not be exerting his full effort during the first test, he should allow five or ten minutes to elapse, during which time other portions of the examination are carried out, and then repeat the test in the usual manner. The results of this procedure are particularly striking when the subject fails to exert his full effort with one hand while he is carrying out the grip with the other hand, as forcefully as possible, so that the injured hand will appear worse by comparison. Under such circumstances, the two tests with the normal hand will show only slight variations, while the tests of the hand which is not exerting full effort will show variations of greater than 20 per cent. between the first and second tests.

CONCLUSIONS

A grip tester having adjustable handle spacings allows a more accurate evaluation of the effect of various types of hand injury. It will also more effectively record the maximum grip of large and small hands. The force of grip is influenced by many factors. These are the size of the object, the effect of previous exercise, handedness, the time of day, age, the state of nutrition, and pain. The failure of the subject to carry out the test with his full effort can be demonstrated by the variation in the force of the grip when the test is repeated.

(*Continued on page 832*)

OPERATIVE TREATMENT OF INJURY TO THE FIBULAR COLLATERAL LIGAMENT OF THE ANKLE *

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From the Seattle Orthopaedic and Fracture Clinic, Seattle

Reports on the subject of injury to the fibular collateral ligament are sparse. What has been written deals primarily with the sequelae of this injury and the relative importance of the three components of this ligament in the maintaining of talotibial stability. At present, operative treatment of this condition is predominantly during a reconstruction stage. Various tenodesis procedures have been recommended by Watson-Jones and Bonnin. Moreover, the surgical treatment has not yet progressed to the stage of primary repair, inasmuch as the diagnosis of a complete tear with subluxation is not readily made at the time of the initial injury.

Forced inversion of the plantar-flexed foot produces the common sprain. In such a case, the anterior talofibular ligament is most commonly ruptured, since this ligament, or fasciculus of the collateral ligament, is practically parallel to the long axis of the tibia when the ankle joint is in this position. Contrary to common thought that this injury constitutes a simple sprain, the authors believe it to be serious. This type of initially severe sprain, however, responds readily to conservative treatment and does not require surgery. When there is an associated rupture of the calcaneofibular or posterior talofibular ligaments, ankle-joint instability is greater and primary surgical intervention may be undertaken.

"Chronic sprain" or "weak ankle" is the term loosely applied to the ankle joint which demonstrates persistent swelling and tenderness following an injury. Recurrent sprains ensue with complaints of weakness and instability of the ankle and inability to run. The plantar-flexed ankle under the stress of weight-bearing is painful. Most of the patients in this series fall into this category.

Accurate diagnosis depends largely on the roentgenographic examination of the plantar-flexed ankle under strain, with or without anaesthesia. Stress must be placed not only on the inverted foot but also in the coronal plane. Loss of parallelism between the articular surfaces of the talus and tibia, with a tilt of the talus in its long axis, indicates rupture of the anterior talofibular ligament and the calcaneofibular ligament. Should the posterior talofibular ligament also be ruptured, the ankle joint is rendered completely unstable (Fig. 1). Rupture of the anterior talofibular ligament alone, however, produces subluxation only in the coronal plane, as previously reported by the authors[1]. Strain in the coronal plane then will demonstrate, in lateral roentgenograms, anterior subluxation of the talus (Fig. 2).

Twenty-seven cases from the Seattle Orthopaedic and Fracture Clinic in which operative treatment has been carried out in the last five years have been collected for this study. It is not intended that this report should serve to present burdensome case histories, but rather to concentrate on the diagnosis of joint injury as well as ligament injury and the rationale of operative treatment.

PATHOLOGICAL ANATOMY

Most anatomical descriptions of the three components of the collateral ligament—anterior talofibular, calcaneofibular, and posterior talofibular fasciculi—are somewhat obscure and at variance. In considering repair, it is essential to inspect the entire collateral ligament. The anterior talofibular ligament is a distinct and sizeable structure from 2

* Read at the Seventeenth Annual Meeting of the Western Orthopedic Association, Sun Valley, Idaho, October 6, 1953.

FIG. 1

FIG. 2

Fig. 1: Anteroposterior roentgenogram made under inversion strain shows gross instability of the ankle joint. (See Figs. 6-A and 6-B for findings at operation.)

Fig. 2: Lateral roentgenogram of plantar-flexed ankle under strain in the coronal plane, showing anterior subluxation of the talus in the ankle-joint mortise.

to 2.5 millimeters in thickness which unites the anterior border of the fibula to the neck of the talus. The overlying capsular tissue must be removed before the ligament is seen. The calcaneofibular ligament, which is stronger, extends from the tip of the fibula to the colliculus on the lateral surface of the calcaneus. It is the only component of the collateral ligament which is extracapsular. The lateral talocalcaneal ligament occupies the space between these two fasciculi, running parallel to the calcaneofibular ligament and blending not only with this ligament but with the anterior talofibular ligament at the anterior aspect of the lateral articular facet of the talus. Lateral capsular tissue in the triangular area between the anterior talofibular and talocalcaneal ligaments blends closely with these structures before passing beneath the calcaneofibular ligament [1]. The posterior talofibular ligament, a very strong band of fibers, extends from the digital fossa of the fibula to the lateral tubercle on the posterior aspect of the talus immediately lateral to the groove for the tendon of the flexor hallucis longus (Fig. 3).

The problem of assessing the relative importance of damage to the various components of the lateral ligament and the effect of such damage on the stability of the ankle joint should be understood. Experimental work relative to this has been undertaken by Chambers, Leonard, and the authors. Generally speaking, there are two types of instability. The first occurs when a tear in the anterior talofibular ligament allows anterior displacement of the talus in the ankle-joint mortise in the coronal plane. In addition, rotational displacement of the talus medially on its vertical axis occurs (Figs. 4-A and 4-B). An associated tear of the lateral capsule may allow a tilt of the talus of as much as 7 degrees. The second type of instability, resulting from a rupture of the anterior talofibular and calcaneofibular ligaments, is exemplified by marked instability in the long axis of the talus. With a combined tear of the anterior talofibular and the calcaneofibular ligaments, tilting of the talus in its mortise may be from 12 degrees to 30 degrees. A rupture of all three ligaments renders the ankle completely unstable. It should be noted that the posterior talofibular ligament

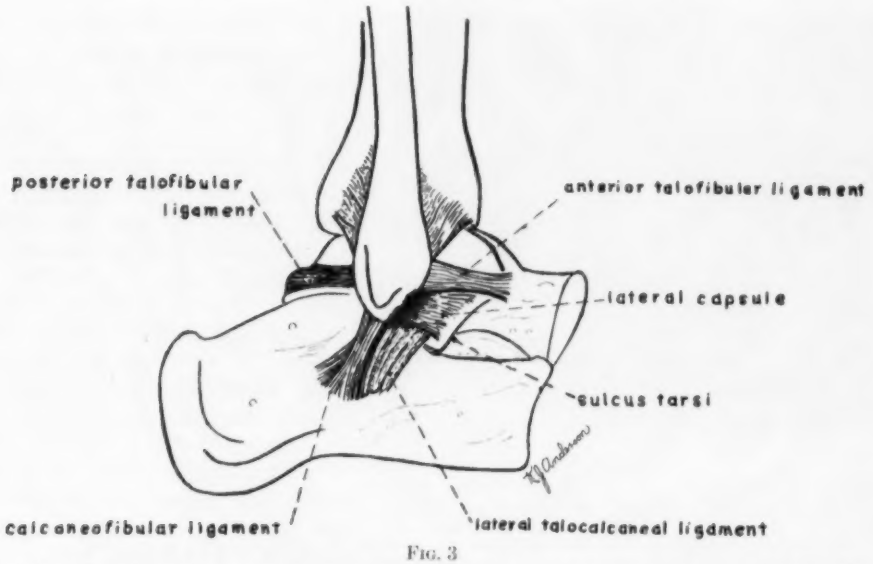

FIG. 3

Schematic drawing showing the ligaments on the lateral aspect of the ankle. (Reproduced from *The Journal of Bone and Joint Surgery*, **34-A:** 857, Oct. 1952.)

remains intact in all but the rarest cases. Of the twenty-seven patients in this series treated surgically, twelve patients fall into the first category, and fifteen fall into the second.

FIG. 4-A

FIG. 4-B

Fig. 4-A: Photograph of right ankle at operation without strain. The anterior talofibular ligament could not be identified. The lateral articular facet of the talus has been exposed. (Reproduced from *The Journal of Bone and Joint Surgery*, **34-A:** 855, Oct. 1952.)

Fig. 4-B: Photograph of same ankle which shows subluxation of the talus with anterior strain. The defect due to osteochondritis dissecans is evident. (Reproduced from *The Journal of Bone and Joint Surgery*, **34-A:** 855, Oct. 1952.)

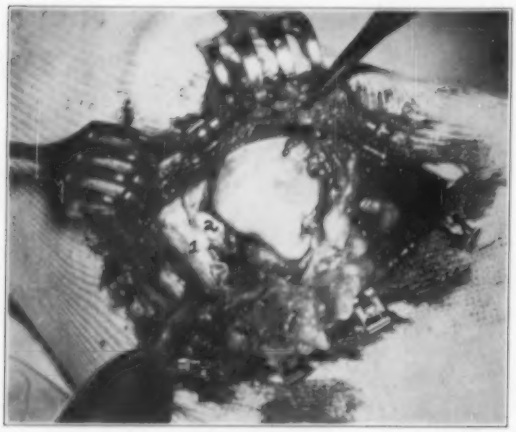

FIG. 5

Photograph of right ankle at operation directly after an acute sprain. The lateral articular facet of the talus is completely dislocated. The anterior talofibular ligament (*1*) obscures the calcaneofibular ligament. The posterior talofibular ligament (*2*) has been stripped from its talar attachment.

TYPE OF OPERATION

Primary repair of tears of the fibular collateral ligament should be reserved for those cases of complete rupture. Although it may seem somewhat radical, the experienced surgeon can readily accept this approach to the problem. The distortion of the ligamentous and capsular tissues and the abnormal anatomy visualized at operation (Fig. 5) demonstrate convincingly that conservative cast immobilization would not give a good result. Again, operative findings in patients first treated conservatively and later operated upon convince one that early repair is justified. If at the time of the original injury patients were placed in the care of surgeons trained in this technique, primary repair would be undertaken more frequently.

Late repair, or reconstruction, of the torn fibular collateral ligaments has proved satisfactory and should be undertaken when control of the disability is not obtained by non-operative means. Reconstruction demands the implantation of new tissues. Those used have been the tendon of the peroneus brevis and the split tendon of the peroneus longus.

FIG. 6-A

FIG. 6-B

Fig. 6-A: Photograph of a left ankle at operation following acute sprain (Fig. 1). The three fasciculi of the collateral ligament have rolled beneath the lateral malleolus just anterior to the peroneal tendons. The lateral articular facet of the talus is dislocated and faces the observer.

Fig. 6-B: Photograph of the same ankle. Hemostats have been placed on the three fasciculi: (*1*) anterior talofibular, (*2*) posterior talofibular, and (*3*) calcaneofibular.

Watson-Jones' original method of tenodesis with slight modification has been used in most instances. Through a lateral approach, the fibula and the anterolateral aspect of the ankle are exposed. The anterior skin flap, as well as the superficial fascia, is dissected forward until the neck of the talus is adequately seen. A careful examination of the three components of the fibular collateral ligament, as well as of the ankle joint, must be done. The calcaneofibular ligament is not seen until the peroneal tendons below the superior peroneal retinaculum are retracted. Exposure of the lateral portion of the posterior talofibular ligament and its fibular attachment is not accomplished until the joint capsule has been opened. The peroneus brevis tendon is then detached from its muscular bed and the peroneus brevis muscle is then sutured to the peroneus longus. The free end of the tendon is then passed through a transverse hole in the lateral malleolus, through a prepared hole in the neck of the talus and finally is sutured to itself behind the lateral malleolus. The tendon is made taut when anchored to such an extent that inversion is completely prevented. Suturing the tendon to itself in front of the malleolus produces a tendinous sheet which completely covers the anterolateral portion of the ankle joint. The retinacular fibers which hold the peroneal tendons in position behind the lateral malleolus must not be disturbed. The capsule is usually imbricated when closed to give additional strength. The ankle is immobilized in plaster for six weeks, with weight-bearing permitted at the third week.

Contrary to the contention of Bonnin that the calcaneofibular ligament is most important, the authors agree with Leonard that the anterior talofibular ligament is the important component of the fibular collateral ligament. Consequently, the above procedure does adequately and specifically correct the pathological anatomy. The anterior talofibular ligament is reconstituted by the double loop of the peroneus brevis tendon, and the attached end of the tendon with its new attachment to the lateral malleolus acts as a new calcaneofibular ligament, limiting excessive inversion. Inversion hypermobility of the ankle is corrected, but within six months all but a few degrees of normal inversion is regained.

DISCUSSION

Data on twenty-seven consecutive cases treated surgically in the past five years (1948–1953) have been used for this study. The average follow-up period has been fifteen months, the longest follow-up being five years and the shortest being three months. There were fourteen females and thirteen males. At the time of surgery, the average age was twenty-nine years, the youngest patient being sixteen years of age and the oldest patient being fifty years of age.

Two patients in this series were treated by primary surgical repair. At operation in each instance, the entire lateral ligamentous and capsular aspects of the ankle joint were found to be torn. The three separate fasciculi of the fibular collateral ligament had been ruptured and lay in abnormal positions (Figs. 5, 6-A, and 6-B). Repair by mattress sutures was sufficient, inasmuch as there was no undue fibrillation of ligamentous tissue. The final result in each case was excellent. The argument for primary repair seems to be strengthened by the fact that three patients who were immobilized in plaster for a period of six weeks following the initial injury, later required reconstruction of the ligaments. In those cases in which the colliculus has been avulsed from the fibula, sound reattachment of the ligament does not always seem to occur with plaster-cast immobilization.

In one patient, the subluxation appeared to be secondary to relaxation of the anterior talofibular and calcaneofibular ligaments following intraligamentous tear. A delayed repair was done by plication of the anterior talofibular and calcaneofibular fasciculi, and a successful result followed. Examination twenty-two months after surgery revealed that the patient was without complaint and able to engage in all activities.

Reconstruction was undertaken in twenty-four cases. Twenty-two operations utilizing

FIG. 7-A

FIG. 7-B

Fig. 7-A: Anteroposterior roentgenogram made under inversion strain shows normal parallelism of the articular surface of the talus and tibia. A complete rupture of the calcaneofibular ligament and relaxation of the anterior talofibular ligament were found at operation.

Fig. 7-B: Lateral roentgenogram made under anterior strain. There is incongruity of joint surfaces.

the peroneus brevis tendon as originally described by Watson-Jones have been performed. This has been done in nine instances for anterior subluxation and in fifteen instances for gross instability. The results have been satisfactory. Hypermobility of the ankle has

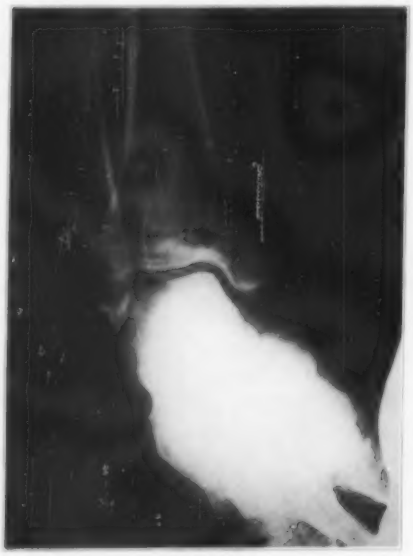

FIG. 8-A

FIG. 8-B

Roentgenograms demonstrating residual instability six months after surgery.

been corrected in each case. Full inversion of the foot returned in twelve cases and in the other ten cases there was loss of inversion of about 25 per cent. Other motions were normal. Full strength was apparent in all patients when rising on the ball of the foot. Subjective complaints, such as aching across the front of the ankle when running, dancing, or after prolonged walking, were presented in three instances. All but one of the patients stated that the instability of the ankle had been relieved. It was noted in this instance that the peroneus brevis tendon had not been made sufficiently taut to prevent all inversion at the time of operation. Stress roentgenograms, taken in each case at the time of the follow-up examination, revealed parallelism of the talus with the tibial articular surface in the anteroposterior view and normal congruity in the lateral view with the single exception mentioned. Male patients were able to return to vigorous activities required in their work by the tenth week following surgery. Four patients incurred subsequent inversion injuries after surgery but had no residual symptoms from this particular injury.

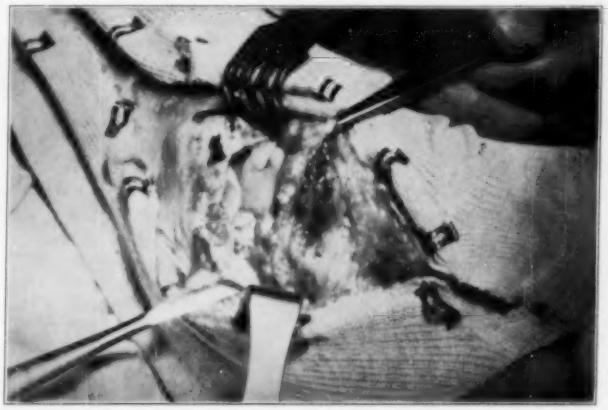

FIG. 9

Photograph of right ankle at operation, showing osteochondritis dissecans of the superolateral aspect of the talus. A loose body lies in front of the lateral malleolus.

Two cases of reconstructive repair have presented inferior results. In one, there was a complete rupture of the calcaneofibular ligament (Figs. 7-A and 7-B). Reconstruction was accomplished by suturing the peroneus brevis tendon to itself just proximal to its metatarsal attachment. Symptoms were partially alleviated, but inversion of the ankle was limited markedly. In retrospect, it appears that, although the anterior talofibular ligament was intact, it was excessively relaxed, and the peroneus brevis tendon should also have been placed through the neck of the talus. The second ankle was treated by the recent procedure described by Watson-Jones, which utilizes the split peroneus longus tendon placed as a sling through the lateral malleolus, tibia, and neck of the talus (Figs. 8-A and 8-B). The poor result in this case was due to a technical failure in correcting the subluxation of the ankle. The authors believe that this procedure does not correct the pathological condition.

Certain complications associated with subluxation of the ankle joint have been noted. Osteochondritis dissecans of the talus was a common sequela to the initial accident or repeated sprains. It was seen in six cases (22 per cent.). The superolateral surface of the talus was affected in five instances and the medial articular surface in one. The diagnosis was made by roentgenogram twice, whereas in four instances the osteochondritis dissecans was not recognized until the ankle had been inspected at operation (Figs. 4-B and 9). Slipping of the peroneal tendons secondary to rupture of the superior peroneal retinaculum was seen on two occasions.

CONCLUSIONS

Operative management of serious injury to the fibular collateral ligament of the ankle is satisfactory. Reconstruction of the late injury is best accomplished by the tenodesis of Watson-Jones, utilizing the peroneus brevis tendon as replacement tissue. Im-

provement in the early treatment of the severe injury can be assured by primary repair.

NOTE: The authors are indebted to Dr. E. A. LeCocq, Dr. D. G. Leavitt, Dr. H. E. Emmel, and Dr. H. H. Nash for allowing their cases to be included in this study, and for rendering assistance in the preparation of this manuscript.

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GRIP TEST

(*Continued from page 824*)

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DISCUSSION

DR. L. D. HOWARD, JR., SAN FRANCISCO, CALIFORNIA: Now that the various problems associated with the testing of grip in industrial injury cases have been presented, I would assume that you are wondering why so much emphasis is placed on grip by the insurance companies when it comes to the final evaluation of disability. Grip in itself, of course, is not a true index of the usefulness of a hand or upper extremity. Grip is a voluntary effort and, as such, is more or less under the control of the patient at all times, and this applies even to repeated tests, with the recording meter hidden.

In most cases, there is a fairly close correlation between grip and muscular development of the forearm. Although this is not indicative in comparisons between individuals, it is an excellent basis for comparison of the injured side with the uninjured side in the single individual. The advantage is that the circumferential measurement of the forearm at a specific point cannot be varied at will by the patient. The combination of circumferential forearm measurement and the amount of wear on the palmar surface of the hand will usually tell the examiner more than a grip test.

DR. DANIEL RIORDAN, NEW ORLEANS, LOUISIANA: I would like to congratulate Dr. Bechtol on his thoroughness. I know that he has been developing this gadget for a long time, and he has worked it into very fine shape.

I have had experience using this grip tester in evaluating force of grip in patients. As he pointed out, it gives the examiner a basis for detecting the degree of function present and the progress made by the patient as he is recovering full strength.

I would like to add one more thing,—the dynamometer is also helpful in rehabilitation of the patient, because it may be used for exercise.

DR. BECHTOL (closing): Attempts to correlate circumferential measurements of the forearm with the force of the grasp have proved to be futile. The musculature of the forearm consists largely of flexors and extensors of the fingers and wrist, whereas the force of the grip is largely dependent upon the musculature of the thenar eminence. The amount of wear on the palmar surface of the hand has likewise proved to be an inaccurate estimate of the force of the grip. Most orthopaedic surgeons, for example, show a very good grip, due to the use of bone-cutting instruments, yet they rarely show any calluses on the palm. A carpenter, on the other hand, may present a very poor grip, yet show a heavily calloused palm due to the friction of constant use of hammers and the handling of lumber.

AN OBSERVATION CONCERNING THE FLEXOR MUSCLES DURING RECOVERY OF FUNCTION AFTER DISLOCATION OF THE ELBOW

BY N. J. BLOCKEY, M.CH.ORTH., F.R.C.S., MANCHESTER, ENGLAND

From the Department of Orthopaedic Surgery, The Royal Infirmary, Manchester

The factors governing the recovery of joint movement after injury are some of the most obscure of the many with which the orthopaedic surgeon is faced in his clinical practice. In planning an intelligent program of rehabilitation after a dislocation or injury to a joint, the orthopaedic surgeon has to admit that there is little scientific evidence to guide him in making the decision as to when the initial period of rest should be ended and the later phase of active movement should be begun. Likewise, he has little guidance as to the value and importance to be attached to the active movements which he prescribes. The orthopaedic surgeon has to fall back on clinical impressions; these may well be misleading when it is considered how widely different the rate of recovery of movement can be after what would appear to be identical injuries.

It seems certain that the recovery of joint movement is not open to simple mechanistic explanations, as are sometimes the bases of the techniques of physical therapy. It also seems clear that repeatedly inflicted passive exercises are particularly resented by joints.

The purpose of this paper is to draw attention to the details of the recovery of movement after dislocation of the elbow joint, an injury in which no bone has been fractured and in which extra articular factors are likely to be minimal. The elbow has been chosen for this study because dislocations of the elbow joint are common and because the elbow and its associated muscles are readily accessible for study.

LITERATURE

Sir Robert Jones, when discussing the treatment of injured joints, stated the generally accepted view that there is a danger of too prolonged fixation, as this gives the newly formed cicatrix time to stiffen. He advised that "when the local effusion and tenderness abate, the patient may be allowed to commence active movements. He is not likely to carry these out sufficiently roughly to tear or damage newly formed scar tissue, because pain will act as a check". Sir Robert Jones repeatedly referred to this natural reflex mechanism,—"Pain is nature's method of controlling voluntary movement which may be harmful".

Nicoll, when discussing the principles of rehabilitation, stated that "the key to success is muscle power". Thus he also subscribed to the mechanistic idea that the recovery of joint range is the result of a struggle between the power of the muscles and the strength of the obstruction limiting movement. According to this concept, an increase of movement is the result of the mechanical obstruction being slowly and progressively pushed aside as the weeks of convalescence proceed.

In the same way Doran, studying stiffness of the elbow after fractures of the humeral shaft, contributed to the simple mechanistic idea in his conclusion that "ability of the arm to overcome any non-osseous obstruction to its movement must depend on the strength of the arm muscle, and, therefore, the stronger the muscles, the greater the chance of recovering a full range of elbow movement". It must be noted, however, that he refers to a man with a compound fracture of the ulnar shaft, who regained a full range of motion at the elbow quite quickly, although the total power in his flexors and extensors was only five pounds (the normal, he states, being thirty to forty pounds).

These observers suggest that the factor which prevents the patient from performing active movements which would damage the newly formed "adhesions" is pain; the infer-

FIG. 1-A

FIG. 1-B

FIG. 2-A

FIG. 2-B

ence being that the patient could do this damage if he could bear the pain which would result. (The word "adhesions" is used here loosely, and no specific pathological condition is implied.)

On the other hand, studying the possible factors responsible for stiffness of the knee after fractures of the femoral shaft, Charnley came to the opposite conclusion. He considered that in the case of extra-articular causes of knee stiffness, which he believed were more important than intra-articular causes after fracture of the femur, there was less harm done to the ultimate range of movement by delay in initiating knee movement than by encouraging early movement. He thus abandoned the simple mechanistic explanation and suggested that the extra-articular causes (loss of elasticity of the muscles involved at the fracture site) were so intimately connected with the process of fracture union and callus formation as to be inseparable. He stated the fatalistic opinion that "when a fracture of the femur reveals a noticeable absence of bony callus in the roentgenogram at about six

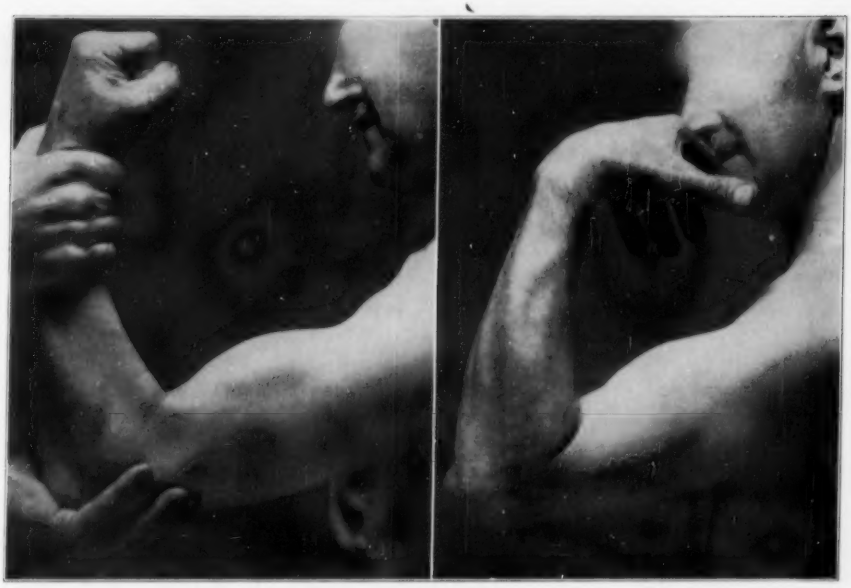

FIG. 3-A FIG. 3-B

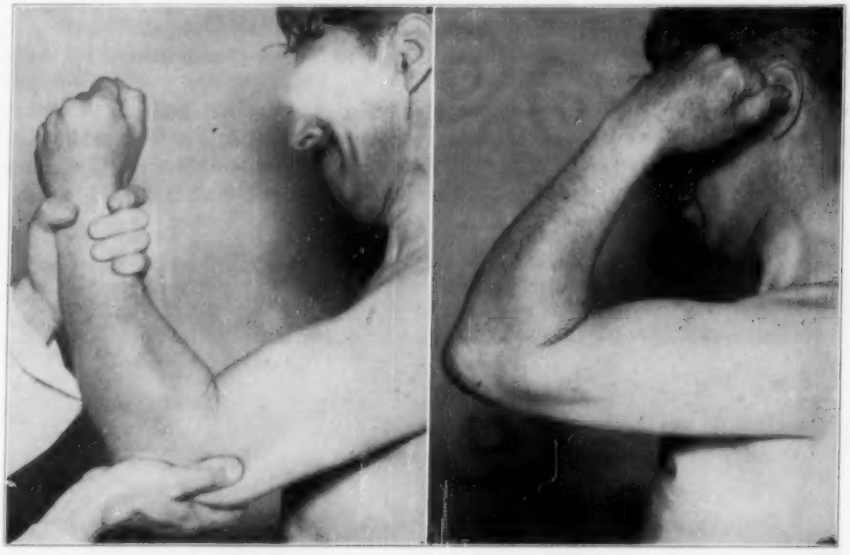

FIG. 4-A FIG. 4-B

weeks, there will always be a threat of limited knee movement, and this will remain even if the femur is treated on an apparatus permitting knee exercise".

CLINICAL OBSERVATIONS

Twenty cases of dislocation of the elbow joint have been studied immediately after reduction and throughout the period of rehabilitation. The sequence of events in the joint, as is generally known, begins at the time immediately after the reduction when any

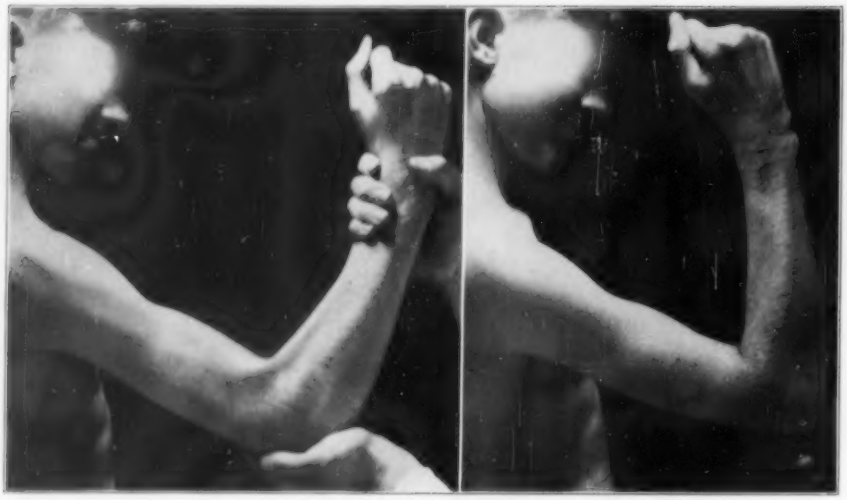

FIG. 5-A FIG. 5-B

passive movement evokes pain. This is succeeded, after a variable period of time, by a phase in which painless movement is tolerated through a slowly increasing arc. The feature of the clinical examination, which is the subject of this communication, is the constant observation that, whereas the flexor muscles are able to contract quite powerfully in the middle range of the painless arc, their contraction is immediately inhibited at the ends of this arc when they come up against the resistance to further flexion offered by the joint adhesions.

This observation is shown photographically in Figures 1-A through 5-B (patients photographed at different times after injury). Figures 1-A, 2-A, 3-A, 4-A, and 5-A show the patient flexing the arm against external resistance, and the profile of the biceps brachii and of the brachioradialis muscles should be noted. Figures 1-B, 2-B, 3-B, 4-B, and 5-B show the patient, all external resistance removed, attempting to flex the elbow as much

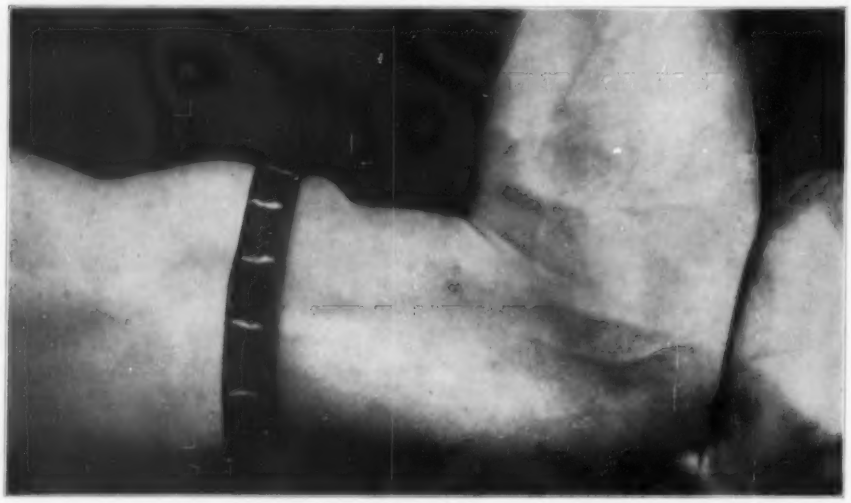

FIG. 6-A

FIG. 6-B

as he can against the resistance of the adhesions around the joint. It will be seen that the profile of these muscles is markedly reduced in size; and at this point the muscles are soft to palpation, and, despite the patient's greatest efforts, no contraction can be detected clinically. Similarly, the triceps is not contracting maximally, and there is no evidence of muscle spasm.

Another example of this clinical examination is seen in Figures 6-A and 6-B. In these a rubber tube is shown stretched around the arm in order to give a photographic impression of the hardness or softness of the biceps. In Figure 6-A, the muscle is hard as it contracts against external resistance. In Figure 6-B, the muscle is seen to be soft, even though the patient is contracting with all the strength at his disposal against the block to flexion offered by the adhesions around the joint. (At the limit of flexion, some of these patients

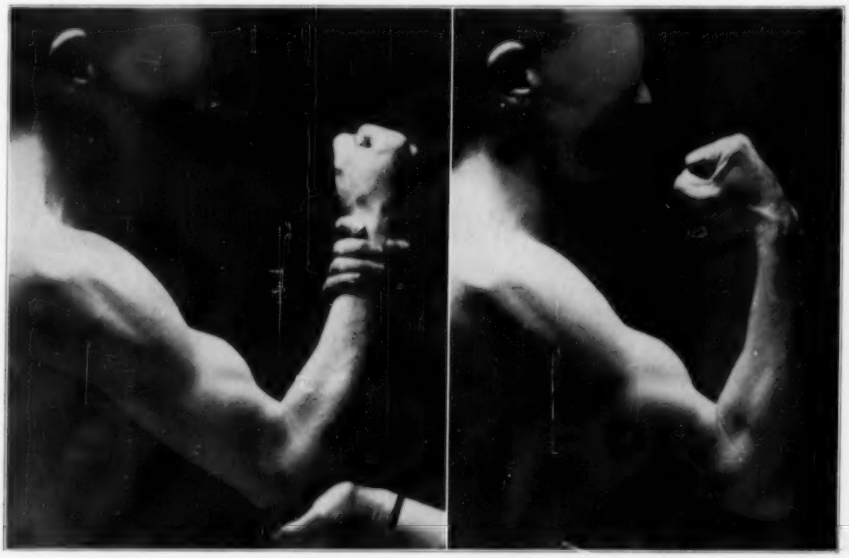

FIG. 7-A FIG. 7-B

experienced pain, but it was infrequent and when present was not of such severity as to suggest that it was this which was preventing their efforts to flex further. Severe pain is only felt when the range of joint motion is increased passively.) In contrast, Figures 7-A and 7-B are photographs of a control. These show that the contour of the flexor muscles is identical in Figure 7-A with external resistance and in Figure 7-B without such resistance.

Evidence from Electrical Recordings

With the use of needle electrodes, the action currents of the biceps brachii were studied with the electromyograph, and with the use of surface electrodes the same action currents were studied with the electro-encephalograph, according to the techniques of Bauwens [1, 2, 3] and Petersén and Kugelberg. Because of outside interference and inexperience with the technique, only eleven recordings were successful (a typical example of these is shown in Figure 8). The other nine showed marked interference patterns and were of no value. It is worth noting that none of these were in contradiction to the figure shown.

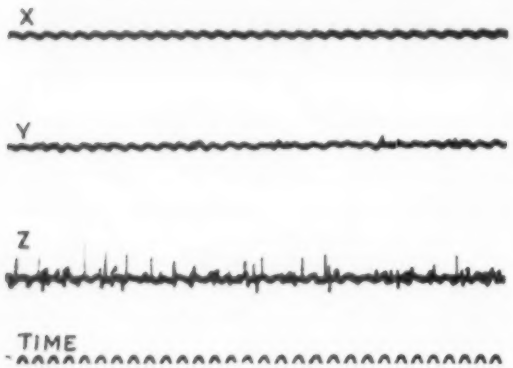

FIG. 8

Resting muscle is electromyographically silent; muscles contracting maximally give action potentials which can be recorded photographically and compared as regards amplitude and frequency with other tracings. Figure 8 shows the typical record obtained in a patient fourteen days after reduction of the dislocation. The trace obtained for resting muscle is seen at *x* at the top of the figure. The bottom trace *z* is the trace of the biceps contracting maximally against external resistance, with the elbow in the middle of the free range

FIG. 9

of movement. The center record *y* is the trace of the biceps contracting against the block to flexion offered by the joint adhesions. It is to be noted that the electromyograph records only a few action potentials, and that these are less in amplitude and frequency than those obtained when the same muscle is contracting maximally against external resistance. Figure 9 shows the action of muscles recorded on a Grass 3 channel electro-encephalograph timed at 1 inch per second. The upper trace is the record of the biceps contracting as much as the patient is able to exert against the block to flexion, and the lower trace was taken when the same muscle contracted against external resistance at the mid-point of the available range.

DISCUSSION

The generally accepted view of the mechanism of joint recovery, as stated in the previously quoted phrases of Sir Robert Jones, states a fact, but it does not help with an explanation. If the cicatrix stiffens when the joint has been immobilized for too long, and yet pain acts as a check to its being torn or damaged, how then is it disposed of? Exactly what mechanical role is filled by active exercises? Doran's case, mentioned earlier, which was exceptional, suggests that there are factors other than muscle power involved in the recovery of range of motion, but he does not draw this inference. The observations here reported would seem to be in direct opposition to the idea that joint adhesions are made to disappear through the action of muscle power impinging against them. It is suggested that some reflex mechanism exists which inhibits the motor muscle at a point just short of that which would be required to break down adhesions. These reported observations therefore suggest that the increase in range of movement in the presence of active exercise is the result of the block to movement retreating as a primary phenomenon, and it is suggested that this retreat or resolution of the adhesions is uninfluenced by muscle power. As their resolution proceeds, the joint regains its range of movement. The stronger the muscles are when a full range is again permitted, the more normal is the arm. It seems that in this lies the value of active exercise, that is, the retention of muscle bulk and strength during the progress of resolution of joint adhesion.

This joint-protection reflex seems to be initiated by receptors other than pain receptors; it does not reach a conscious level. It is possible that it might be abolished by the infiltration of the damaged joint with a local anaesthetic, and then a state might be reached where voluntary movements could add further damage to a joint. May this not be the method of evolution of Charcot's joints?[7]

Phenomena suggesting the existence of such an inhibiting reflex are commonplace in a mixed orthopaedic practice. The inability of a man to perform static quadriceps contraction in the immediate few days following meniscectomy is surely accounted for in this way. Charnley, in discussing fractures of the femoral shaft, stated that "the earliest sign of late angulation is diminution of knee movement". This is a diminution produced not by pain but by the sheer inability of the patient to contract the muscles when the limit of the range of joint motion has been reached. The marked stiffness in knee and ankle joints seen after the conservative treatment of fractures of the tibial shaft is only partly accounted for by the immobilization of these joints. The stiffness is severer in degree and duration than that seen after a similar fracture which has been adequately plated. This difference adds weight to the suggestion that the syndrome of pain, wasting, osteoporosis, and glossy skin with subcutaneous oedema are all signs of difficulty of fracture union and that muscle inhibition is a contributory factor. Gasser gives us our definition: "Inhibition is a term of convenience used without exact definition in connection with a group of phenomena having certain qualities in common. The essential condition is a stoppage or prevention of action through the temporary operation of a process which does not harm the tissue." In the explanation of these phenomena it is clear that pain is not the whole story, and it is suggested that limitation of movement which would otherwise damage healing tissues is inhibited by a reflex, a reflex whose path is unknown. One can do no better than to conclude this digression with the words Lloyd used in his discussion of the nature of central inhibition: "One can only wait for future endeavor to provide the basis for a better understanding".

Both types of electrical recording apparatus used in this study showed that at the limit of active movement, although the flexor muscle was flaccid, there was some electrical activity. A study of further cases of recovery of movement following joint injury suggests a definite correlation between time since injury, range of movement present, and the number and amplitude of action potentials. It is hoped to enlarge on this in a subsequent paper.

CONCLUSIONS

Increase in joint range following dislocation of the elbow occurs by resolution of the products of joint damage. This resolution is a primary phenomenon and is not the result of the power of the muscles overcoming the tenacity of the adhesions.

At any period during convalescence the joint permits a range of movement, at the limit of which the muscles which could further increase this range are inhibited.

It is suggested that reflex inhibition is widely applicable in the treatment of trauma and that the pain alone does not exert the checking influence previously ascribed to it.

NOTE: The author's thanks are due to Mr. John Charnley for his careful supervision of this work; to Mr. D. L. Griffiths and Dr. L. A. Liversedge for their help; and to the Department of Medical Photography of the Manchester Royal Infirmary for the excellence of the photographic material.

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DISCUSSION

MUSCLE-PEDICLE BONE GRAFTS

(*Continued from page 809*)

The authors have demonstrated without doubt that an isolated segment of bone in a short muscle-pedicle graft can repair a fracture in the same segment. In this now-established fact lies what I believe to be the greatest contribution of this paper. Could a longer muscle pedicle which was twisted on itself maintain nourishment of a muscle-pedicle graft transplanted at a distance? Additional experiments are necessary for the answer to this and other questions, in order to prove or disprove the practicability of using muscle-pedicle bone grafts in the human.

DR. JOEL HARTLEY (closing): I would like to thank the discussors, Dr. Davis and Dr. Lipscomb, for being so kind. It seems worth while to pursue further laboratory studies in order to get more basic facts concerning this problem. I think that in certain situations we can begin to do procedures on patients, such as Dr. Davis has done so skillfully, and to get some additional clinical data.

TREATMENT OF CHRONIC BONE INFECTION

BY J. G. SHANNON, M.D., AND F. M. WOOLHOUSE, M.D., MONTREAL, QUEBEC, CANADA

From the Orthopaedic and Plastic Services of the Queen Mary Veterans' Hospital, The Montreal General Hospital, and The Children's Memorial Hospital, Montreal

The purpose of this presentation is to report the results of treatment in eighty-two cases of chronic bone infection which have come within our purview during the past five years. In broad terms, the surgical management comprised immediate skin-grafting of the debrided lesion and, when necessary, the subsequent filling of the defect with cancellous-bone chips covered with a pedicle of skin and subcutaneous tissue.

This procedure is not new. The authors, among others, have previously reported a smaller series [6, 7], although with some timidity because of the short follow-up. It is now believed that, with a much larger series and a greatly increased follow-up period, a somewhat more authoritative opinion can be ventured as to the value of the method.

The use of skin grafts in the treatment of chronic bone infection was first advocated in 1922[5]. During and since the last War considerable impetus has been given to this type of treatment and in the past few years a number of reports on this method have been made, notably those of Mowlem; Kelly, Rosati, and Murray; and Knight and Wood.

The method employed in this series differs from those previously reported in one respect only, that the split-skin graft has always been directly applied to the bone at the time of excision of the infected area. Kelly and his coworkers reported having done this in a few of their cases.

It appears to us that a skin graft applied at the time when the fibrosed soft tissues and involved bone are excised has considerable merit. No difficulty has been experienced in securing a satisfactory "take" of the skin. If any minute pieces of detached bone are left on the surface of the cavity, they will perforate the skin graft and the small defect will quickly epithelialize. If, on the other hand, a larger area of infected or eburnated bone has been allowed to remain at the time of débridement, there will be a corresponding slough in the skin graft. Such an area can be re-excised and covered with a small skin graft.

This immediate application of suitable skin to the cavity protects the bone exposed at the time of débridement from the ingress of additional infection and prevents the pocketing of soft-tissue infection by obliterating all dead space. This method also arrests the progressive fibrosis of the soft-tissue walls because it permits healing by primary intention.

METHOD

Treatment is divided into two stages as follows:

The patient's general condition is assessed. If it is one of severe debilitation, it is ameliorated as much as possible by diet, blood transfusions, and antibiotics. Frequently, however, the patient's general condition cannot be greatly improved until after excision and skin-grafting have been completed. The patient is operated upon under general or spinal anaesthesia and all scarred fibrotic and necrotic soft tissue is widely excised. The infected and sclerosed area of bone is also widely excised to leave a surface of healthy bone which bleeds freely.

When all infected tissue has been removed, the area is freely irrigated with normal saline solution, care being taken that no small particles of detached tissue, whether bone or soft tissue, are left in the wound. A split-thickness skin graft of suitable size is applied to the area to cover both bare bone and denuded soft tissue. This graft is sutured at normal skin tension to the margin of the wound. Complete coaptation of the surfaces is obtained

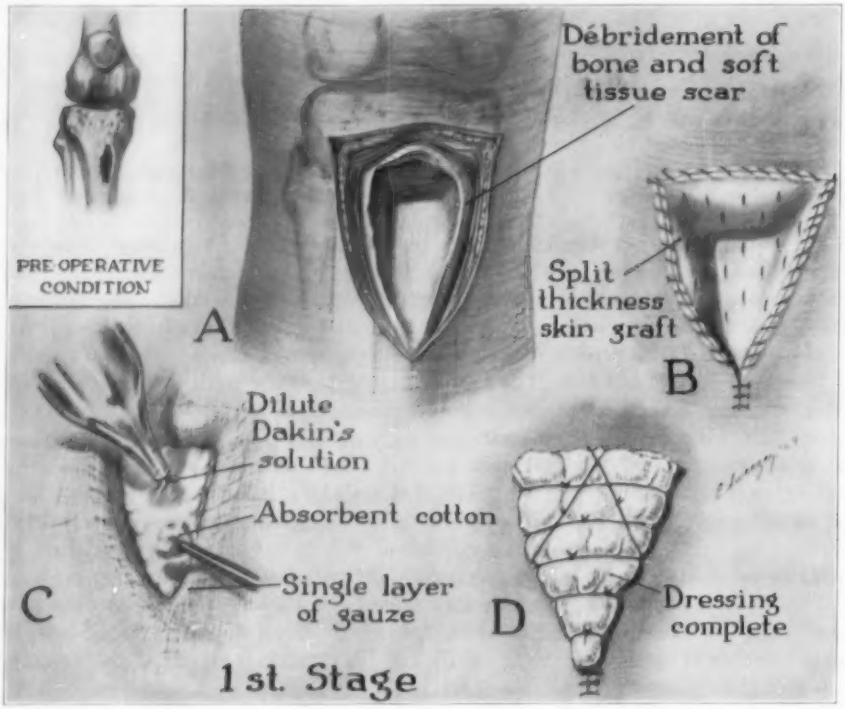

FIG. 1

Schematic drawing showing radical excision of bone and soft tissue and application of split-thickness skin graft.

by a meticulously applied pressure dressing, which is held in place by retaining sutures (Fig. 1). A plaster cast is then applied to immobilize the part.

Ten to twelve days later the wound is dressed and the sutures are removed. If the excision has been complete, one may expect an almost 100 per cent. take of the graft. A pressure dressing is re-applied and maintained for an additional ten to twelve days. In the lower extremity a skin graft requires pressure support for an additional three weeks. At the end of this time the first stage is considered complete.

The patient is kept under observation for a minimum of two months more before the second stage is undertaken. During this period, if the structure of bone will permit, the patient is encouraged to pursue his ordinary activities.

The second stage is likewise carried out under general or spinal anaesthesia. The split-thickness skin graft is removed and the surface of the bone is freshened by curettage. The defect in the bone is filled with closely packed cancellous-bone chips removed from the ilium, or in certain cases with a cortical graft and cancellous-bone chips. The surface is then covered with a pedicle graft of skin and subcutaneous tissue in such a manner that the graft overlaps the edges of the bone defect. This may frequently be done with double-ended or single-ended pedicles of contiguous tissue, or it may be necessary to use a pedicle graft or tube-pedicle graft from another part of the body. The donor area is covered with a split-thickness skin graft (Fig. 2). The part is again immobilized in plaster until the grafts have been soundly incorporated into the recipient area.

RESULTS

Of the eighty-two cases of chronic osteomyelitis, fifty-nine were gunshot wounds and

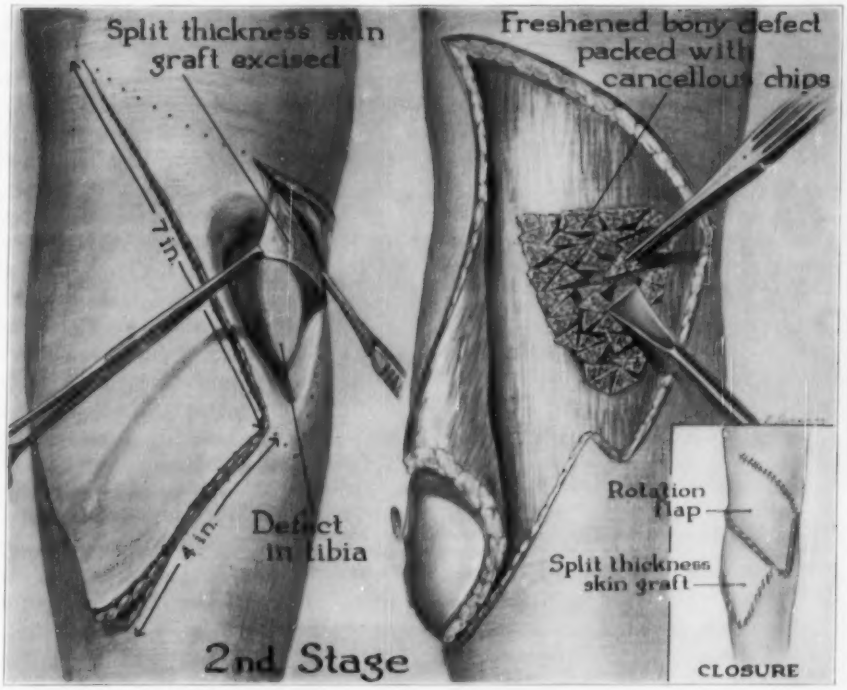

FIG. 2

Schematic drawing showing removal of the split-thickness skin graft, freshening of defect, packing of cavity with cancellous bone, and closure with overlapping pedicle graft.

compound fractures of the long bones. When the patients came under our care, the infection was already well established, and in most cases there was extensive soft-tissue scarring. There were seventeen cases of hematogenous osteomyelitis, ten of which were in children. Four cases of tuberculosis of joints and two cases of septic arthritis of the hip joint complete the series.

Seventy-two lesions are healed; by this we mean that the area is completely covered with skin, or skin and subcutaneous tissue, or skin, subcutaneous tissue, and muscle; that no drainage is present; and that the patients are pursuing normal activities. Ten lesions failed to heal.

Of the eighty-two first-stage procedures done, the lesions are healed in seventy-five (91.5 per cent.). Of the thirty-eight second-stage procedures, the lesions are healed in thirty-four (89.5 per cent.).

Of the seventy-two patients with healed lesions, the first stage only was done in forty-four. We consider the treatment to be completed at the end of the first stage, unless the bone structure is inadequate for the normal function of the part, or unless it is believed that the soft-tissue coverage will be insufficient for full functional activity. It should be noted that the split-thickness skin graft directly adherent to the bone defect becomes much thicker and surprisingly resilient as time goes on. We have never completed the second stage when we thought it was unnecessary, nor have we been urged to do so for cosmetic reasons.

Of the fifty-nine cases of exogenous osteomyelitis—that is, infected compound fractures and gunshot wounds—forty-nine lesions are healed, twenty-three required only the first stage of treatment, and twenty-six required the second stage. All the failures were in this group. Persistent or intermittent drainage had been present for periods ranging

FIG. 3

A woman, thirty-six years old, had hematogenous osteomyelitis which had been draining intermittently for twenty-two years. Complete excision necessitated tunneling through the femur. A split-skin graft was applied immediately.

FIG. 4

Showing a typical healed defect of the distal end of the femur.

from a few months to thirty-three years. Some of these patients had sustained their injuries in World War I, but the majority had been injured in World War II and in these the infection had been present from one to five years. The follow-up period since healing has been from one to six years. Two of the patients with failures had severe wounds of the proximal end of the tibia with extensive infection of the knee joint; and two had similar lesions involving the ankle joint. Two patients had large defects in the tibia with infection of most of the remaining portion of the shaft and extensive ischaemic soft-tissue scarring. In these we were able to complete the first stage successfully, but when we attempted the reconstruction of the tibia, necrosis of the bone chips took place—the result, we believe, of inadequate blood supply. There were no unusual features associated with the remaining failures.

In all the seventeen patients with hematogenous osteomyelitis, the lesions are healed. In five cases the bone defect was of such size as to warrant completion of the second stage. Of these latter patients, four were children.

There were four cases of tuberculosis of joints, of which three were in the hip and one in the shoulder. In the lesions of the hip, the head and neck of the femur were excised. The acetabulum was curetted, all tuberculous tissue was excised, and the skin graft was then applied. In two of these cases the magnitude and activity of the lesion were such as to make us feel that the procedure was life-saving. The lesion of the shoulder joint was similarly treated. All of these lesions are healed. The immediate systemic improvement in the patients in this group was particularly dramatic.

There were two cases of septic arthritis of the hip joint. One of these was a man, fifty-five years of age, in whom the lesion had been draining intermittently since infancy; the other was an infection of the acetabulum in a man who had undergone a disarticulation for septic arthritis. These lesions were treated in the same manner as the tuberculous hip joints and healed promptly.

Bacteriologically, the cases, excepting those of tuberculosis, fall into three groups. In the first group, Staphylococci and superficial infections with Proteus, Pseudomonas, and Aerobacter organisms were found. In the second group, Staphylococci only were found. In the third group, no Staphylococci were found, but Proteus, Pseudomonas, Aerobacter, or other organisms were present.

The failures were greatest in the first group, less in the second group, and least in the third group. However, the number of cases in each group was so small that the figures are not significant.

There are certain aspects of this treatment which we believe are of paramount importance. In the first instance, it is important to realize that a large area of diseased bone and soft tissue can be radically excised and a split-thickness skin graft can be applied immediately. If this excision does not in any way jeopardize the functional proclivities of the part, it suffices as the final definitive procedure (Fig. 3). This is also illustrated by the following case.

F. C., a man, thirty-three years old, first had hematogenous osteomyelitis at thirteen years of age. This had drained persistently for twenty years. In 1946 the infected area was radically excised and a skin graft was applied immediately. A cavity, four inches long and extending through to the opposite cortex, remained in the lower end of the femur. There was a 100 per cent. take of this graft. This was supported by a pressure dressing for a month, at the end of which time the patient was allowed full activity, which has been maintained ever since. The subsequent production of fibrous connective tissue under the skin graft has formed a resilient, tough covering for the bone (Fig. 4).

FIG. 5-A

Roentgenogram showing an infected gunshot wound which involved the knee joint.

Secondly, it should be pointed out that, as long as the diseased area of bone is adequately excised, the shape of the remaining defect will not influence the result, since complete coaptation of a skin graft can be attained (Figs. 5-A to 5-E). This is well illustrated by the following case.

D. R., a man, twenty-five years old, had sustained a gunshot wound of the proximal end of the right tibia. This had become infected and had drained for three years when he came under our care. In order to retain the quadriceps attachment to the tibial tubercle, excision of the infected area required tunneling through the proximal end of the tibia.

The filling-in of the defect in this case demonstrates the remaining cardinal points of the method, namely, the freshening of the cavity by a sharp curved osteotome after the skin graft has been removed, packing the cavity tightly with cancellous-bone chips, closing the wound in depth, and arranging the skin and subcutaneous covering in such a way that its margins lie beyond the limits of the bone cavity (Figs. 6-A to 6-C).

The cases of tuberculosis of the hip joint were particularly interesting.

A. G., a white male, forty-six years old, came under our care in 1947. He was extremely emaciated and in constant pain. He was running a high swinging temperature, and had extensive tuberculosis of the right hip joint which was draining from multiple sinuses. The disease had been present for twelve years and treatment had been completely inadequate. When we first saw him, he was in an extremely precarious condition.

It seemed to us that the logical treatment in this case was disarticulation of the hip joint. However, because of our previous experience with extensive pyogenic infection of

FIG. 5-B

Fig. 5-B: The infected area was excised.

FIG. 5-C

Fig. 5-C: A split-thickness skin graft was used to cover the lesion.

FIG. 5-D

FIG. 5-E

Figs. 5-D and 5-E: The defect was filled with cancellous-bone chips and covered with a pedicle graft.

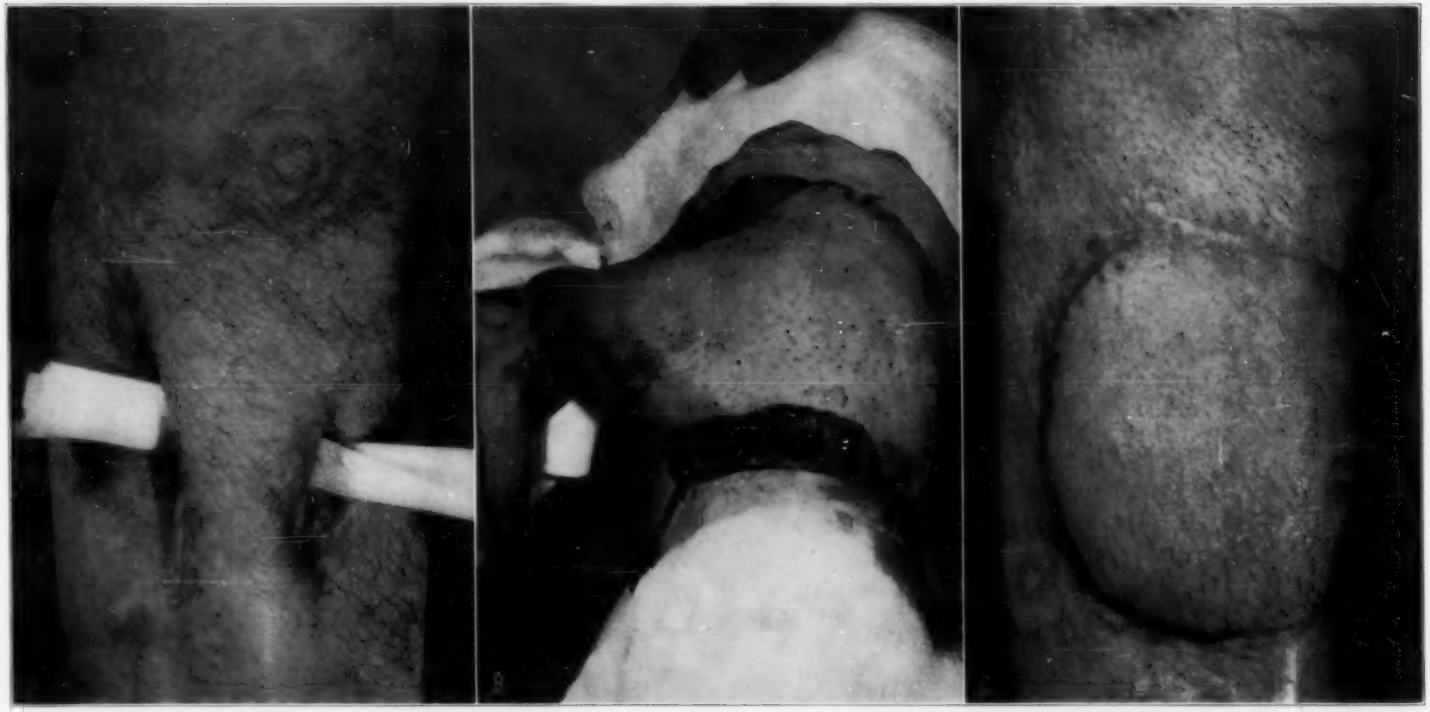

FIG. 6-A

FIG. 6-B

FIG. 6-C

Fig. 6-A: An infected gunshot wound required tunneling of the tibia to preserve the quadriceps insertion.
Fig. 6-B: The cavity was packed with cancellous-bone chips and covered with an overlapping pedicle graft.
Fig. 6-C: Showing healed lesion.

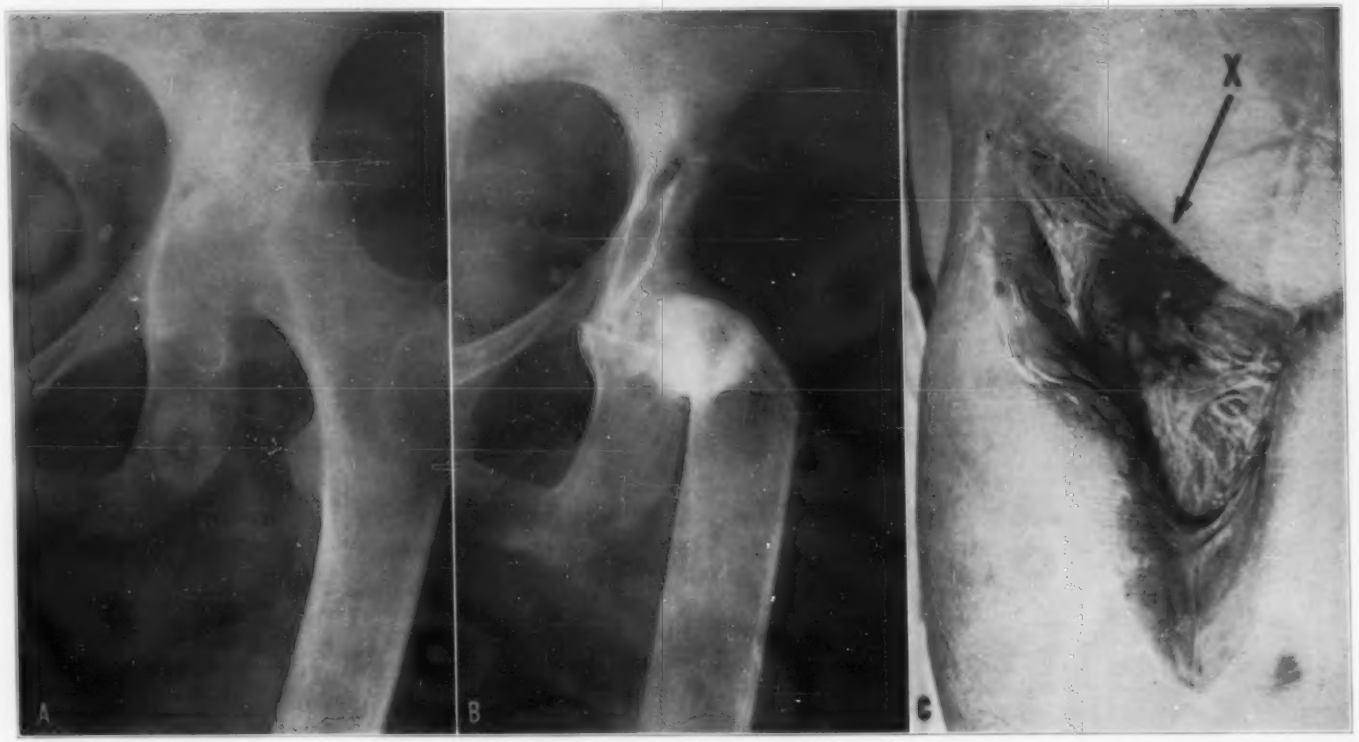

FIG. 7-A FIG. 7-B FIG. 7-C

Fig. 7-A: Roentgenogram showing tuberculosis of the hip joint.
Fig. 7-B: Roentgenogram made after excision. (Figs. 7-A and 7-B were accidentally reversed to show a left hip. They should show a right hip.)
Fig. 7-C: Photograph of the healed lesion. The dark area (*X*) represents the skin graft in the acetabulum.

bone, we believed that we could eradicate the tuberculous lesion by excision and skin-grafting, thus saving the extremity and subjecting the patient to a less severe and less mutilating operation.

This procedure was performed and the patient's general systemic improvement immediately after operation was remarkable. We estimated that he had gained about twenty pounds by the time his first dressing was changed ten days after operation. There was a complete take of the skin graft. His general improvement continued. He left the Hospital at the end of six weeks, walking on crutches. We had no further information about this patient until he walked into the Clinic on November 20, 1951, at which time he was well and the lesion had remained entirely healed. Stabilization of the hip should be done, but so far the patient has refused it.

In March 1948, a white female, thirty-six years of age, who had just recovered from a right nephrectomy for a tuberculous kidney, was admitted to our service. She had tuberculosis of the fourth and fifth lumbar vertebrae, and draining sinuses in both groins. The disease had been present since 1945. With immobilization of the spine and the administration of streptomycin, the sinuses stopped draining. A spine fusion from the third lumbar vertebra to the sacrum was done in July 1948. In March 1949 it was discovered that she had tuberculosis of the right hip. A Brittain arthrodesis was done. Progress was satisfactory until June 1950, when renal colic from multiple calculi developed in the remaining kidney. Apparently as a result of the debilitating effects of the latter lesion, there was an exacerbation of the tuberculosis in the hip and her general condition deteriorated rapidly. She was having frequent attacks of renal colic, running an acute febrile course, and had lost a great deal of weight.

We felt that this patient had to be made ambulatory at all costs and that we could not continue the orthodox treatment of tuberculosis of the hip. At the same time we felt that by excision and skin-grafting we could eradicate the tuberculous hip lesion and thereby remove one of the main factors in the cause of the renal disease.

This was done in June 1950. Improvement began immediately. The lesion healed completely and the patient was up on crutches five weeks later. This patient gets about the house without crutches, but walks with crutches outside. So far she has not returned for stabilization of the hip joint (Figs. 7-A, 7-B, and 7-C).

Of the two hips with septic arthritis, one had been draining intermittently from multiple sinuses for fifty-five years. This was treated in the same manner as the tuberculous hip joints. The lesion healed promptly and the improvement in the patient's general condition was remarkable. We had intended subsequently to fuse the proximal end of the affected femur to the pelvis. However, the patient is working regularly at a job which requires constant standing and walking. The joint is apparently stabilized by the deep fibrosis between the pelvis and the limb, developed over the fifty-five year period during which the lesion was active. This man can actually walk two miles comfortably and he sees no reason for further operative intervention.

SUMMARY

The authors believe that the radical excision of diseased bone and of the ischaemic and fibrosed soft tissue, the immediate covering of the defect created with a split-thickness skin graft, and, when necessary, the subsequent filling of the defect with bone covered with a pedicle skin graft constitute the best treatment for chronic infection of bone.

While these procedures obviously are not advocated as a routine treatment for joint tuberculosis or septic arthritis, it is believed that their usefulness in certain of these cases has been demonstrated.

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GIG PULL-OUT SUTURE FOR TENDONS

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The gig pull-out suture, based on the principle of the gig on a spear for catching fish, was developed in order to simplify and to speed up the suturing of tendons. It is useful in extensive primary repairs, in inserting tendon into bone, and, at times, for tendon suturing other than at insertions. It holds the tendon distally until the tendon unites; it is then withdrawn.

Experiments with different sorts of barbed sutures showed that the narrow barbs cut through and pulled out at three to four pounds,—that is, before the breaking point of the single No. 34 stainless-steel wire was reached. The gig, however, presents a broad flat surface which withstands a strain greater than the breaking point of a double No. 34 stainless-steel wire.

If the suture is passed through the tendon in one direction only, it will cut through; but if it is passed through the tendon in two directions—one at a right angle to the other—so as to cross tendon fibers, it will hold.

A single No. 34 wire stretches and then breaks at about four and a half pounds; double wire breaks at about seven and a half pounds.

Unless the three holes through the gig are beveled, the wire will be cut at the edges of the holes. Since the edges of these holes have been beveled, the wire has stretched and has broken at the hemostat which held it or along its length, but the wire has not broken at the gig. The gig suture held against a greater strain than the wire would tolerate. In narrow tendons, the suture slid through the tendon at a six-pound and seven-pound pull, but in a tendon the size of a flexor sublimis it held firmly and more strongly than the wire. Each time at a pull of seven and a half pounds the wire would stretch and break. A repaired tendon pulls only intermittently, and usually does not pull harder than three to five pounds. A narrow tendon will have less pull. More than half the cross section of the tendon at the site of repair retains its blood supply.

The placing of the suture is simple. The needle bearing the two ends of the wire, which is looped through the two central holes in the gig, is passed transversely through the tendon and again transversely through it at a right angle to the first. The doubled wire is then passed down through the tendon a short distance through the wrist, palm, digit, or bone, and out through the skin where it is tied over a button. The holes in the gig are placed a little eccentrically, so that the point of the gig will dig in. The pull-out wire, looped through the narrow long end of the gig, is brought out through the skin proximally and is left there. In three weeks, the wires are cut off beneath the button. It is

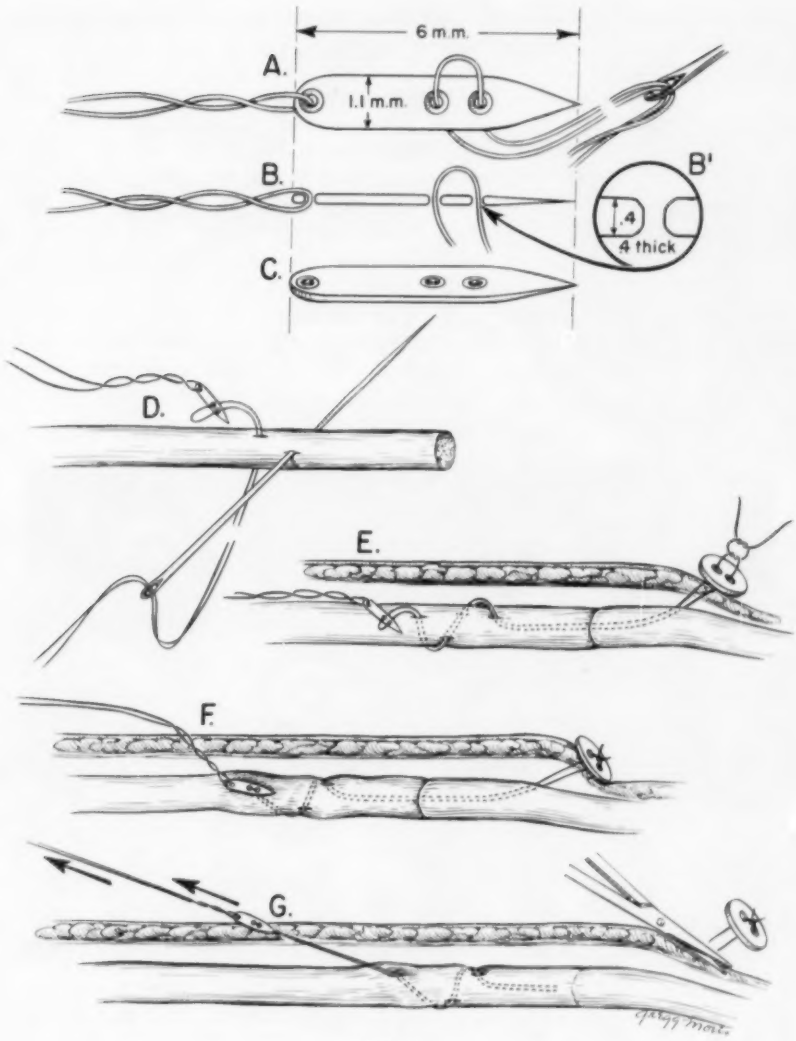

FIG. 1

A, *B*, *B'*, and *C:* The gig has been enlarged. The size, threading, and beveled edges of the holes are shown.

D: The needle is thrust through the tendon twice; the direction of the second thrust is at a right angle to that of the first thrust.

E and *F:* The suture is passed through the center of the tendon, the distal end of the tendon, or bone, and out through the skin for external anchorage to a button.

G: When the tendon is physiologically united, the suture is withdrawn.

surprising how easily the gig can then be withdrawn by the pull-out wire. The tendon by that time has united and will be free from suture.

The gig is made of hard stainless steel, and is six millimeters long, 1.1 millimeters wide, and .4 millimeter thick. It should be kept already wired and separately wrapped, since it is so small that it is easily lost. It may be used repeatedly. We have used our regular wire pull-out suture for many years, and our clinical tests of the gig suture on patients have shown that the use of the latter is just as satisfactory.

SERRATUS ANTERIOR PARALYSIS TREATED BY TRANSPLANTATION OF THE PECTORALIS MINOR

BY IRA H. RAPP, M.D., CHARLOTTE, NORTH CAROLINA

To Velpeau is given the credit for recognition, in 1837, of the clinical entity arising from paralysis of the serratus anterior and resulting in the so-called "winged" scapula. The serratus anterior arises by muscular interdigitations from the first eight ribs of the lateral aspect of the chest wall and inserts into the vertebral border and the inferior angle of the scapula. Mechanically it is excellently situated to hold the scapula to the chest wall while the arm is being raised and it supplies rotatory motion to the scapula, so that full abduction elevation of the arm may be accomplished. Paralysis of its nerve supply results in a rather characteristic backward protrusion of the vertebral border and inferior angle of the scapula, rotation of the scapula due to the weight of the arm, and marked limitation of abduction elevation of the arm with active muscular effort (Fig. 1). The resultant weakness of the shoulder is seriously disabling to the manual laborer.

FIG. 1

The illustration was taken from a movie made before operation. Note winging of the scapula upon attempted elevation of the arm.

The innervation of the serratus anterior is supplied by the long thoracic nerve, which is derived from the anterior nerve roots of the fifth, sixth, and, in most cases, the seventh cervical segments. This nerve traverses the greater part of the scalenus medius and runs from behind the first part of the axillary artery to course quite superficially along the axillary and lateral border of the serratus anterior, which it supplies. It is this long course which makes the nerve particularly susceptible to a variety of toxic and injurious agents. Paralysis of the long thoracic nerve or the external respiratory nerve of Bell may be due to the direct or indirect trauma of accidental injury, exposure to cold, toxic agents, or infection. Hansson, in reviewing twenty-eight cases, found that seven were due to trauma, three to postoperative injury, three to post-tetanic serum injection, two to poliomyelitis, and thirteen to exposure.

The problems involved in the surgical treatment of serratus anterior paralysis are the provision of fixation of the scapula to overcome shoulder weakness and the re-estab-

lishment of rotatory motion necessary to accomplish full abduction elevation of the arm. Whitman in 1932 and Dickson in 1937 described methods for fixation of the scapula by attachment of fascial slings from the vertebral border of the scapula to the posterior spinous processes of the thoracic vertebrae and ribs.

In the search for muscle transplants which would not only provide stability to the shoulder but would also replace a similar functional motor for a paralyzed serratus anterior, Tubby, as early as 1904, described a procedure wherein the sternal portion of the pectoralis major was used as the muscle transplant. Durman also used a portion of the pectoralis major as a replacement transplant, while Hass used the teres major. More recently, Herzmark employed the rhomboids with a satisfactory result.

From the description of the numerous procedures employed for the treatment of winged scapula, it is evident that no one technique has been generally

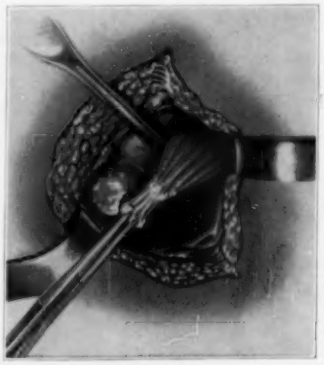

FIG. 2

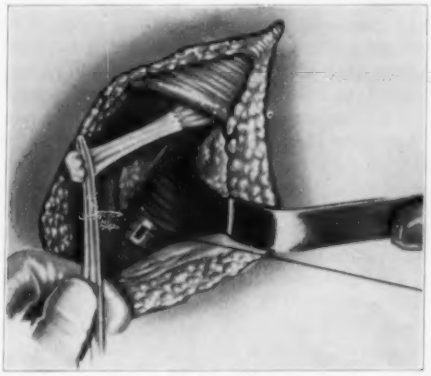

FIG. 3

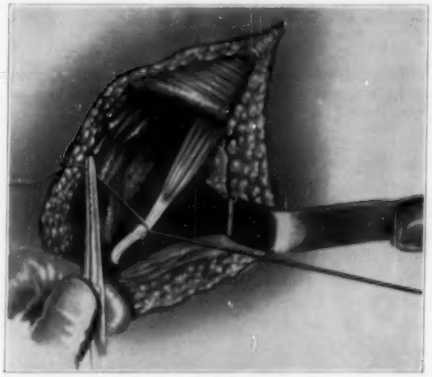

FIG. 4

Fig. 2: The pectoralis minor has been detached from its insertions into the coracoid process. The periosteal elevator indicates the depth to which dissection has been carried to free the muscle from the chest wall, while its nerve supply is preserved.

Fig. 3: The clamp holds the fascial prolongation of the pectoralis minor which is to be attached through a window made in the inferior angle of the scapula (indicated by the silk suture).

Fig. 4: After the suture has been passed through the window in the inferior angle of the scapula, it is turned back upon itself.

adopted. In reviewing the problems involved and in studying the regional anatomy and the muscles available for transplantation, it seemed logical to conclude that the pectoralis minor has a decided mechanical advantage. This conclusion was reached by Chaves, who described a case in which the pectoralis minor was used with an excellent end result. The pectoralis minor originates from the second, third, fourth, and fifth ribs near the costochondral junction and is inserted into the coracoid process. The muscle is innervated by the medial anterior thoracic branch of the brachial plexus, which enters the middle third of its muscular portion. It becomes apparent that, after detachment of its insertion from the coracoid process, the muscle fibers may be made to parallel those of the serratus anterior by directing the transplant toward the inferior angle of the scapula.

It is the purpose of this paper to describe in some detail the surgical technique employed in transplantation of the pectoralis minor to the scapula to act as a replacement for a paralyzed serratus anterior muscle. It is hoped that similar cases may be considered suitable for this procedure.

FIG. 5

Photograph demonstrating the range of motion nine months after surgery. Note the slight prominence of the vertebral border of the right scapula.

A lineman, forty-five years old, fell a distance of twenty feet on December 23, 1950. He landed on his back and sustained injuries to his head, lumbar spine, and right shoulder. A spine fusion extending from the third lumbar vertebra to the first sacral segment was performed on May 28, 1951, for a traumatic spondylolisthesis of the fourth and fifth lumbar vertebrae. In May 1952 the patient continued to complain of pain and weakness of the right shoulder on abduction elevation and clinical examination revealed persistent and complete paralysis of the right serratus anterior muscle with inability to extend the arm above 80 degrees. Efforts at extension were accompanied by winging of the scapula, which occasioned considerable disability in the patient's manual work, especially in lifting and pushing (Fig. 1). He was reluctant to wear a brace. Consequently, on May 19, 1952, a transplantation of the pectoralis minor was performed.

The patient was positioned on the operating table with the right shoulder in rotation of 30 degrees to the left. This position was maintained by means of sandbags under the shoulder and scapula. The arm was held extended and abducted at an angle of 120 degrees and was fixed to a Mayo stand. An incision was begun along the mid-portion of the right clavicle and curved around the coracoid process in the direction of the anterior fold of the axilla. The pectoralis minor was identified; it was detached from the coracoid process and dissected free from the surrounding soft tissue to the middle third of its muscle belly, where its innervation was identified (Fig. 2). The incision was continued in the direction of the inferior angle of the scapula, but was terminated in the posterior axillary line. A tunnel was created beneath the pectoralis major and through this was passed the tendon of the pectoralis minor. A lateral incision was then made in the right thigh, while the upper portion of the shoulder incision was closed. A strip of fascia lata, five by ten centimeters, was removed from the thigh; this was attached to the pectoralis minor muscle and tendon (Fig. 3). (The fascia lata prolongation was found to be necessary as the pectoralis minor tendon lacked approximately 2.5 centimeters of meeting the inferior angle of the scapula.) During the dissection of the lower portion of the wound, the thoracodorsal nerve to the latissimus dorsi was visualized and carefully retracted. It was also noted that the serratus anterior muscle had the typically gray appearance of a paralyzed muscle. The inferior angle of the scapula was cleared by subperiosteal dissection and a window was made to accommodate the fascial prolongation of the pectoralis minor, which was introduced, reflected back upon itself, and sutured in this position (Fig. 4).

After closure and dressing, the limb was immobilized in a Velpeau bandage. The Velpeau immobilization was discontinued six weeks after surgery and a program of active exercise was instituted. Figure 5 shows the range of abduction elevation nine months after surgery. Although a minimal protrusion of the vertebral border of the scapula is evident in the photograph, the patient is not hindered in his efforts at manual labor.

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RESECTION OF THE BODY OF THE PUBIC BONE, THE SUPERIOR AND INFERIOR PUBIC RAMI, THE INFERIOR ISCHIAL RAMUS, AND THE ISCHIAL TUBEROSITY

A Surgical Approach

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From the Veterans Administration Center, Dayton

A patient was presented who required the removal of the body of the pubic bone, the superior and inferior pubic rami, the inferior ischial ramus, and the ischial tuberosity for chronic osteomyelitis following a urinary-bladder injury with resulting sinus-tract formation. A review of the literature failed to reveal a surgical approach to these parts other than that reported in Milch's article [1] on the resection of the ischium. Milch's approach was used as the basis for developing a more extensive exposure to include the inferior pubic ramus, the body of the pubic bone, and the superior pubic ramus. An approach of this type may be indicated for surgical treatment of chronic osteomyelitis, bone tumor, or tuberculosis.

The approach to be described was first worked out and developed by anatomical laboratory dissection. With the patient in the lithotomy position, with his buttocks elevated and his feet placed in stirrups, an incision is made through the skin and subcutaneous

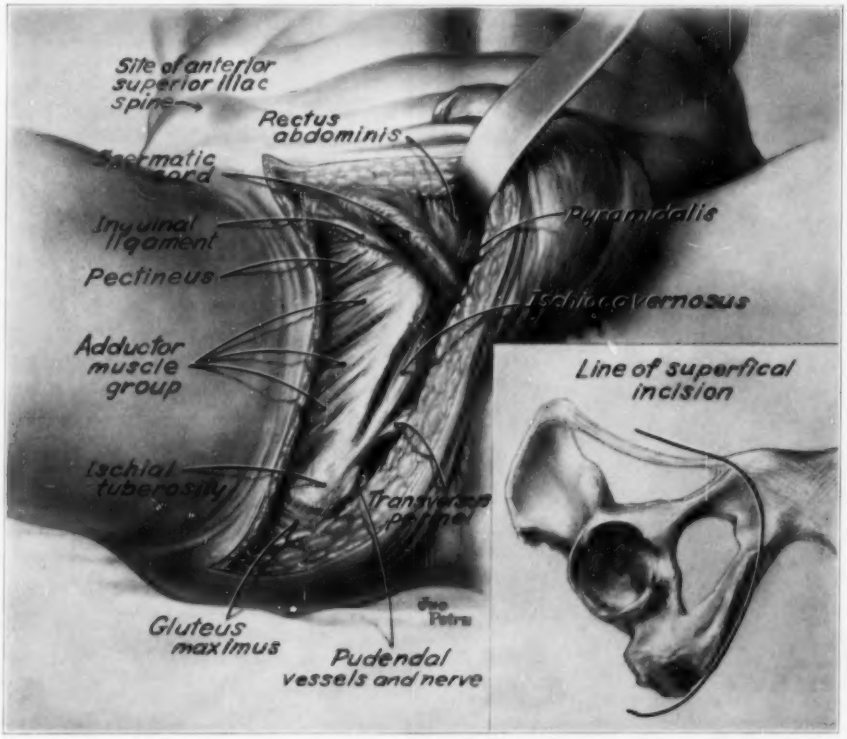

FIG. 1

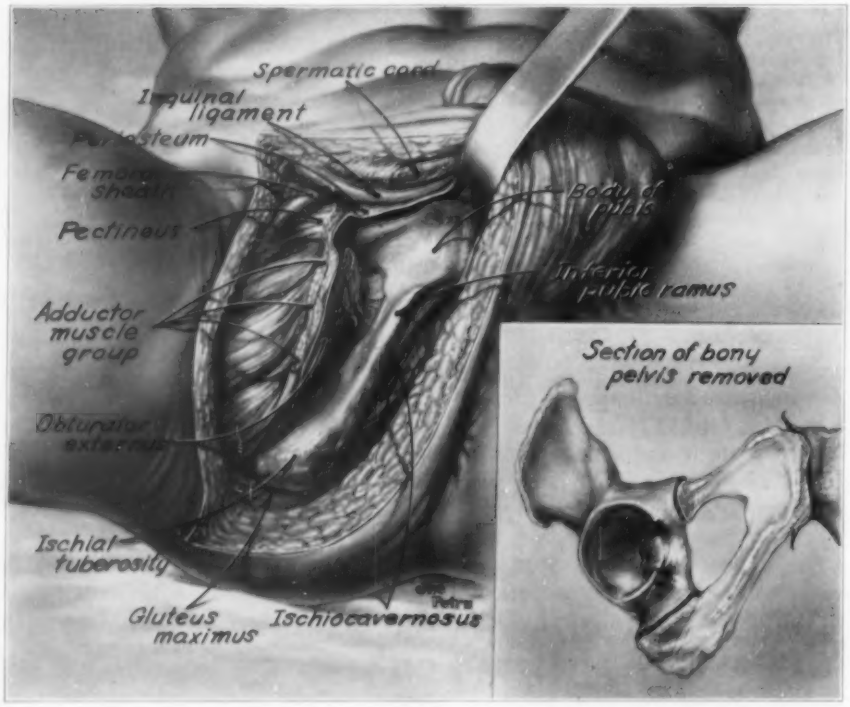
Spermatic cord
Inguinal ligament
Pectineus
Adductor muscle group
Ischial tuberosity
Gluteus maximus
Ischiocavernosus
Section of bony pelvis removed

FIG. 2

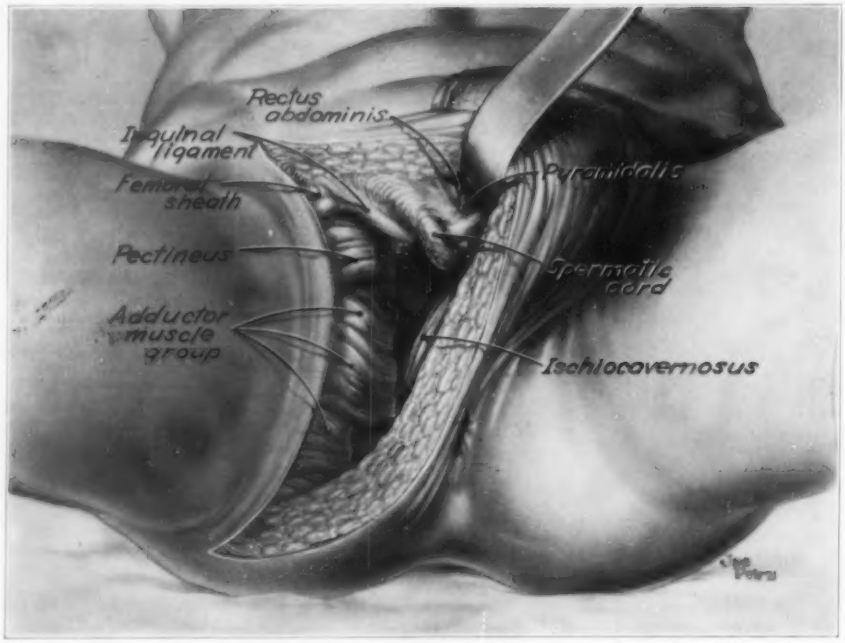
Rectus abdominis
Inguinal ligament
Femoral sheath
Pectineus
Adductor muscle group
Pyramidalis
Spermatic cord
Ischiocavernosus

FIG. 3

tissue 0.6 centimeter below the mid-point of Poupart's ligament and runs parallel with and inferior to the ligament (Fig. 1).

The incision is carried medially and inferiorly to the base of the lateral aspect of the penis and inferiorly along the lateral border of the scrotum, inferior ischial ramus, and ischial tuberosity. The incision is then carried down through the deep fascia. Attention is next directed to developing the lower portion of this approach before one moves superiorly to the region of the more delicate structures. The adductor group of muscles and the obturator externus are removed subperiosteally by sharp and blunt dissection from their pelvic attachments; thus a part of the body of the pubic bone, the lateral border of the inferior pubic ramus, inferior ischial ramus, and ischial tuberosity are exposed. The latter can be further exposed by retracting or cutting the lower edge of the glutaeus maximus in line with the incision. The hamstring muscles and the quadratus femoris can then be removed from the lateral aspect of the ischial tuberosity, and the sacrotuberous ligament can be removed from the medial aspect. Care must be exercised to avoid injury to the pudendal vessels and nerve which emerge from the pelvis through the greater sciatic foramen; these cross the spine of the ischium and sacrospinous ligament to enter the lesser sciatic foramen, and they proceed anteriorly in Alcock's canal along the medial border of the inferior ischial ramus and the inferior pubic ramus within the fascia of the obturator internus muscle. This canal, together with its contents, is avoided by carrying out a subperiosteal dissection of the ischiocavernosus and obturator internus. During this part of the dissection, the transversus perinaei profundus and superficialis, crus penis, and the constrictor urethrae are removed subperiosteally from the medial borders of the inferior ischial ramus and the inferior pubic ramus, as the dissection is carried to a point just below the symphysis pubis. The urogenital diaphragm is dissected from one half of the inferior border of the symphysis pubis. Extreme care must be exercised to avoid injury to the urethra, deep dorsal vein of the penis, and the dorsal artery and nerve of the penis at this point. The rectus abdominis and the pyramidalis are next removed from the region of the crest of the pubis. The pectineus is removed totally or in part from its origin at the pectineal line of the superior pubic ramus, the inguinal ligament already having been elevated from the pubic tubercle. The femoral sheath and its contents lie on the lateral portion of the pectineus and must not be involved with the mobilization of the pectineus muscle itself. In completion of the subperiosteal mobilization of the obturator externus and obturator internus, the obturator nerve and vessels may be encountered. If at all possible, these structures should be preserved (Fig. 2).

With the exposure completed the actual resection of the bony structures is best carried out by the careful use of a double-action rongeur, especially in the region of the pectineus and the symphysis pubis. The ischial tuberosity may be transected by the use of an osteotome or Gigli saw (Fig. 3). Closure is satisfactorily accomplished in clean cases by permitting the muscles to return to their original positions and by suturing the deep fascia. If the wound is infected, the muscles are permitted to return to their normal positions, but closure of the fascia is not carried out, thus permitting adequate drainage. Postoperative dressings sealing off the wound from the other perineal orifices is indicated.

A case report of a patient upon whom the previously described surgical approach was carried out is presented.

A white male, forty-five years old, was well until May 15, 1949, at which time he received a gunshot wound of the abdomen. The site of entry was to the right of the suprapubic region, and the site of exit was through the right side of the perineum. After several urological surgical procedures, the patient was admitted to the Brown Hospital, Veterans Administration, Dayton, Ohio, on February 25, 1953, with the diagnoses of urethrocutaneous fistula, located in the right inguinal region, and chronic osteomyelitis of the right pubic bone. Several attempts were made to restore the continuity of the urethra, but these attempts proved to be unsuccessful. On October 5, 1953, sequestrectomy and débridement of the body of the right pubic bone, the right superior and inferior pubic rami, the inferior ischial ramus, and the ischial tuberosity were carried out.

At the same time the fistula was excised *in toto*. His postoperative course was uneventful except for a slight amount of serous drainage from the mid-point of the incision. This cleared up completely in two weeks. Postoperative roentgenograms showed the chronically infected area to be cleared of all sequestra. The patient was placed on progressive physiotherapy exercises, and one month after surgery was discharged ambulatory and asymptomatic, except for his permanent suprapubic cystotomy.

NOTE: Appreciation is expressed to the Departments of Anatomy and Medical Illustration, University of Cincinnati, College of Medicine, for making their facilities available for the anatomical dissections and drawings.

1. MILCH, HENRY: Partial Resection of the Ischium. J. Bone and Joint Surg., **17**: 166–171, Jan. 1935.

DISCUSSION

STEINDLER FLEXOPLASTY AT THE ELBOW

(*Continued from page 789*)

DR. R. E. CARROLL, NEW YORK, N. Y.: There is no doubt that the best method of restoring motion to the elbow is the Steindler flexorplasty, and I, too, would like to pay tribute to Dr. Steindler.

If it is advised that the operation to restore motion at the elbow should be done only when full function of the hand is present, I cannot agree. An operation which will enable a man to place his arm on a table to write, to oppose a functional grip, or to lift his forearm is very useful and should be done. As far as possible we want to salvage the hand first. It is my feeling that, when we are going to use the tendons of the superficial flexor mass for reconstruction of the hand, we should first complete the flexorplasty. With this new point of origin, the functional power of these tendons can be obtained. After this the transplantation in the hand may be performed. In our experience this has proved to be the best procedure.

As for the problem of the carrying angle in the elbow, I am impressed by the ability of Dr. Mayer's patients to extend their elbows completely after the pronator-flexor muscles of the hand and forearm have been moved 6.3 centimeters up the humerus as well as anteriorly. It is true that in younger patients full extension may be close to 180 degrees. We have many adult patients in whom this cannot be done. We find that we can expect an approximate 40-degree carrying angle. This is quite a useful angle, as functional motion is made in flexion. In poliomyelitis, moreover, the triceps is often weakened; perhaps the weakened triceps often accounts for the resultant flexion angle.

Dr. Steindler has discussed the problem of how to correct pronation deformity by using the flexor carpi ulnaris. I agree with him. Dr. Mayer brought out the fact that a pronation deformity can occur when this operation is performed. We have corrected this defect by an ulnaris transplant.

DR. WILLIAM H. FRACKELTON, MILWAUKEE, WISCONSIN: Appreciation goes to Dr. Mayer and to Dr. Steindler for this fine presentation. If Dr. Mayer or Dr. Steindler had discussed the indications for this procedure at greater length, they probably would have offered further indications for its use. Let me give as an example a boy who had two paralytic upper extremities, one totally paralyzed and the other retaining activity only in the scapular and forearm flexor muscles. It was possible for the patient to eat, help himself in dressing, and perform other daily tasks with the latter arm after the following procedures: an arthrodesis of the humerus to the scapula; a Steindler flexorplasty at the elbow; and arthrodeses of the wrist, of the thumb in a position of opposition, and of the metacarpophalangeal joints of the fingers. Thus, although only the flexor tendons about the wrist were active, it was possible for the patient to flex the fingers in useful pinch and grasp and to flex the elbow.

DR. DON L. EYLER, NASHVILLE, TENNESSEE: I think that, if one could choose the discussor for his paper, one could do no better than to ask Dr. Mayer. Those of us entering the field of orthopaedics would do well to emulate him. Too often, we are apt to be hypercritical in remarks made on the spur of the moment. Dr. Mayer is at all times a gentleman as well as a scholar, and I have never heard him discuss a paper when he did not compliment the speaker, as well as give pertinent constructive criticism.

In Dr. Mayer's modification, the internervous plane of Henry is utilized and, by insinuating a finger in this plane, one can carry the dissection proximally "with the grain" of the musculature without danger of damaging vital structures. By blunt and sharp dissection a muscle mass made up of the flexor digitorum sublimis, palmaris longus, flexor carpi radialis, and the superficial head of the pronator teres can be quickly mobilized and the common aponeurotic origin can be freed from the medial epicondyle. The dissection is in

(*Continued on page 862*)

MONOSTOTIC COCCIDIOIDAL INFECTION

Report of a Case Successfully Treated with 2-Hydroxystilbamidine

BY COLONEL ALFRED A. GREBE

Medical Corps, United States Army

From the Orthopaedic Service, United States Army Hospital, Fort Hood, Texas

Infections due to *Coccidioides immitis* are classified by Smith [1] as initial or primary infections, which run a self-limited course and are nearly always focalized in the lungs, and progressive, secondary, or disseminated infections.

Because of the benign nature of the majority of the pulmonary infections, the incidence of dissemination is not known, but it is estimated to be one in 500 to 1,000 of all infections. However, when dissemination does occur, the outcome is usually disastrous.

To the present time there has been no known therapeutic agent which would alter the course of the disease and once dissemination occurred the usual result has been death or, if dissemination was not too wide-spread, amputation of the involved part.

The purpose of this paper is to report a case of monostotic coccidioidal infection which did not respond to repeated wide excision of the bone lesion, but which did show rapid and apparently complete healing when treated with 2-hydroxystilbamidine.

CASE REPORT

The patient was a colored male soldier, twenty-one years old, who was born in Pensacola, Florida, and had lived there all of his life until February 24, 1951, at which time he was inducted into the Service. He received training at Fort Jackson, South Carolina, and Fort Riley, Kansas. Approximately six months after induction, he was assigned to the Far East Command, and was sent to Korea by way of Seattle, Washington. He remained in Seattle approximately three weeks before sailing.

Soon after his arrival in Korea he was assigned to a combat unit, and on August 16, 1951, he was shot by a sniper's rifle bullet in the left heel. He was treated in Japan for approximately three months, after which time he was evacuated to the United States. He landed at Travis Air Force Base, California, and remained there for approximately three weeks before being sent to Fort Benning, Georgia. By the time he arrived at the latter station his wound was virtually healed, and most of the following two months he spent on convalescent leave in Florida.

The patient stated that he had had no serious illness in the past. Prior to entry in the military service he had had mumps and an occasional acute upper respiratory infection. He had German measles shortly after induction into the Service. There was no history of respiratory infection while he was in the Service. The family history was non-contributory.

In March 1952 he was assigned to Fort Hood, Texas, apparently having completely recovered from his injury. During his tour of duty at this post, his general condition remained good and he performed full military duty until the early part of July 1952, at which time, early one morning, he noticed a painful sensation in the left heel. This became progressively worse and failed to respond to treatment in the local dispensary. He was admitted to the Fort Hood Army Hospital on July 28, 1952, at which time a very

Fig. 1

Lateral roentgenogram of the left calcaneus made shortly after onset of symptoms. No evidence of disease or injury was noted.

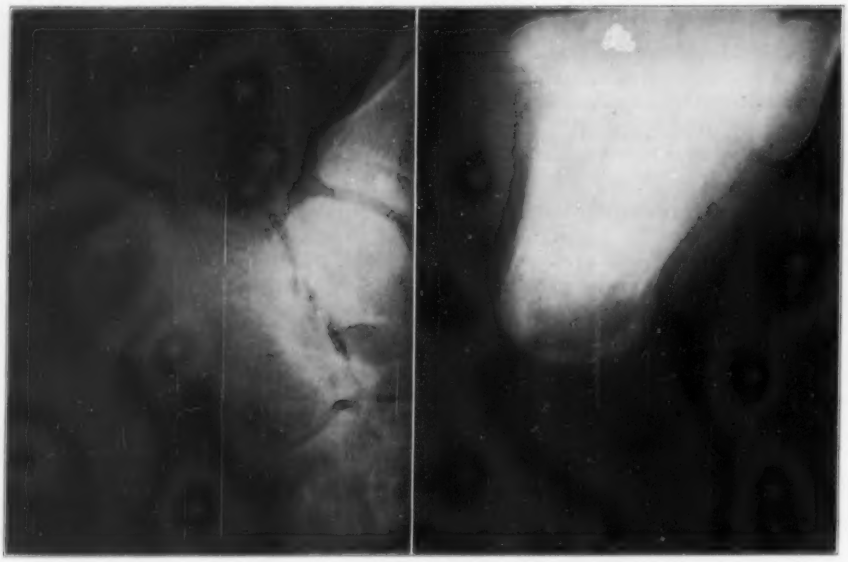

FIG. 2
Four weeks later definite bone destruction was seen in both lateral and tangential views.

tender, reddened, fluctuant area approximately two centimeters in diameter was noted on the lateral aspect of the left heel. Roentgenographic studies of the left heel at the time of onset of the symptoms were reported as negative. It is interesting to note that these studies did not reveal any evidence of bone damage from his combat injury (Fig. 1).

On admission to the Hospital the physical examination was entirely negative except for the lesion of the left heel. The temperature was normal. The red blood count, hemoglobin, and sedimentation rate were within normal limits.

White blood cells		8,400
Neutrophils	65	
Lymphocytes	28	
Monocytes	4	
Eosinophils	2	
Basophils	1	

The urinalysis was negative, as were serological findings.

Treatment on admission consisted in application of local heat, elevation of the left foot, and 200,000 units of penicillin twice daily. On the following day the abscess was incised and a small amount of thick, odorless, purulent material was evacuated, which was reported as sterile on culture. After a few days the incised area ulcerated and continued to discharge a very small amount of seropurulent material. The ulcer showed no tendency to heal and repeated roentgenographic examinations showed a rapidly progressing area of destruction in the tuberosity of the calcaneus (Figs. 2 and 3).

In view of the progressive destruction which this lesion exhibited, it was decided to excise it. This was done on September 9, 1952. At that time not more than a very thin wall of the tuberosity of the calcaneus had remained, and this was removed. One small necrotic bone fragment was found to be lying free in the region; this was removed, together with the entire wall of the bone cavity, until only apparently normal, healthy bone remained. The wound was packed open. Tissue removed at the time of operation was sent to the laboratory, and it was at this time that the diagnosis of coccidioidal infection was made. In view of the laboratory report, roentgenographic studies of the chest were made on September 23, 1952, and were reported as negative.

Excision of the lesion brought relief of pain and the wound healed slowly by granulation, except for persistence of a small sinus. A moderate amount of serous exudate continued to drain from this, and repeated cultures revealed coccidioidal organisms. Several roentgenograms showed no further evidence of bone destruction until the early part of February 1953, when the patient again complained of pain and roentgenograms revealed further evidence of bone lysis (Fig. 4). On February 16, 1953, the wound was re-explored and a small amount of necrotic bone, together with a large amount of necrotic inflammatory tissue, was excised. The wound was again left open.

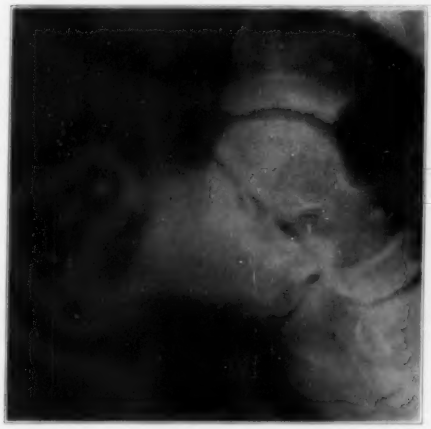

FIG. 3

FIG. 4

Fig. 3: Rapid progression of the destructive process was seen after seventeen days.

Fig. 4: Approximately four months after excision of the lesion, symptoms recurred and further bone destruction was seen.

Fig. 5: Roentgenogram made after three months of therapy with 2-hydroxystilbamidine; no further evidence of bone destruction was noted.

FIG. 5

On March 23, 1953, treatment with 2-hydroxystilbamidine was instituted. This was given in doses of 225 milligrams dissolved in ten cubic centimeters of 5 per cent. dextrose solution intramuscularly five days a week. The drug was apparently well tolerated, except for extreme discomfort at the site of injection, and after sixteen injections it was decided to administer the drug intravenously, dissolved in 200 cubic centimeters of 5 per cent. dextrose given by the slow-drip method over a period of thirty minutes. Except for a brief period during the time when our supply of the drug was exhausted, this treatment was continued until the patient had received a total of twenty-four grams. The last injection was given on July 16, 1953.

After approximately two weeks of treatment, there was complete relief of pain and marked reduction in drainage from the wound was noted. Healing of the wound was progressive and, by the middle of May 1953, drainage had ceased completely.

Repeated roentgenograms of the lesion made at approximately monthly intervals showed no further evidence of bone destruction. The roentgenologist's report, dated June 16, 1953, was as follows: "Films of the left os calcis again show the postoperative defect involving the calcaneum. The edges are smooth, indicating that there has been healing." (Fig. 5.)

Laboratory Data

Repeated laboratory studies after admission showed no significant variation from normal except on June 10, 1953, when acute appendicitis developed. At this time the white cell count rose to 12,250, with 80 per cent. neutrophils. Repeated smears and cultures of the exudate from the lesion in the heel were all negative for bacteria.

On September 19, 1952, thick-walled, endospore-filled spherules typical of *Coccidioides immitis* were seen by direct examination of material removed by surgical excision. Culture of this material also produced growth of Coccidioides. Repeated cultures of exudate from the lesion were reported as positive on November 17, 1952, and again on March 20, 1953. This last culture was made three days before treatment with 2-hydroxystilbamidine was begun. Two additional cultures were made on April 13, 1953, and on April 21, 1953, but failed to produce growth of the organism.

Before treatment with 2-hydroxystilbamidine was instituted, coccidioidin skin tests were performed. It was found that 0.1 cubic centimeter of 1:100 dilution of coccidioidin failed to produce a reaction, but the same amount of antigen in 1:10 dilution produced an erythematous area one centimeter in diameter which

was interpreted as a weakly positive reaction.

Serological tests for coccidioidal infection were performed at the University of California School of Public Health and were reported as follows:

"Complement Fixation:	1:2	1:4	1:8	1:16	1:32
February 18, 1953	+ + + +	+ + + +	+ + +	+ +	0
March 26, 1953	+ + + +	+ + + +	+ + + +	+ + +	0
May 14, 1953	+ + + +	+ + + +	+ + + +	+ + + +	0
September 3, 1953	+ + + +	+ + + +	+ + + +	+	0
November 20, 1953	+ + + +	+ + + +	+ + + +	0	0

"Precipitin tests: repeatedly negative."

The patient exhibited no clinical signs of toxicity as a result of the administration of 2-hydroxystilbamidine. Before 2-hydroxystilbamidine therapy was begun, liver-function and kidney-function tests were performed. These tests were repeated during the course of treatment, and at no time was any significant variation from normal noted. The only complication occurred, as already stated, when acute appendicitis developed. Operation was performed on the same day with uneventful recovery.

After the last injection of 2-hydroxystilbamidine, the patient was kept under observation without treatment for approximately six months, during which time laboratory tests for liver and kidney function and complement-fixation tests were repeatedly performed. No evidence of visceral damage from the drug was ever demonstrated and a continued reduction in titer in the serological tests was noted. No further evidence of bone destruction of the left calcaneus was demonstrated on the roentgenograms. The operative wound remained healed. The patient had no complaints of discomfort and was able to walk long distances with no more than a barely perceptible limp. On December 3, 1953, he was discharged from the Hospital.

COMMENT

In presenting this case, the author is cognizant of the fact that a favorable outcome in one case in which a new drug is used leaves much to be desired in the assessment of the true value of the drug. Certainly, a longer follow-up is desirable, but in the meantime it is hoped that the apparent cure effected in this case will stimulate further trial of treatment of disseminated coccidioidomycosis with 2-hydroxystilbamidine and that the results of its use in a larger number of cases will be made known.

NOTE: The writer wishes to express his thanks to Dr. Michael L. Furcolow, University of Kansas Medical Center, for suggesting the use of 2-hydroxystilbamidine and for his help in procuring the drug, and to Dr. W. Gerald Morson of the Wm. S. Merrell Company, Cincinnati, Ohio, for making the drug available. An expression of appreciation is also due Dr. Charles E. Smith of the University of California for the interest which he exhibited in this case and for performing the serological studies which are reported in the text. Dr. I. Snapper of the Cook County Hospital, Chicago, rendered a most welcome service in suggesting the total dosage of the drug to be used.

1. SMITH, C. E.: Coccidioidomycosis. Med. Clin. North America, **27**: 790–807, 1943.

DISCUSSION

STEINDLER FLEXOPLASTY AT THE ELBOW

(*Continued from page 858*)

a relatively avascular field, the median and ulnar nerves and the ulnar artery are plainly visible at all times, even though no special dissection or attempt is made to expose them, and a large mobile mass of muscles is available for transfer.

I would like to compliment Dr. Mayer on his presentation and to pay due respect to Dr. Steindler, who fathered this ingenious procedure.

DR. MAYER (closing): I want to thank all the discussors most cordially for their kind words, and particularly to Dr. Carroll I want to say that difference of opinion is what makes for progress. I am delighted that he has advanced an alternative procedure and that we will have a chance to see which method is better. Personally, I think it is better to work first on the hand and then on the elbow, but I may be wrong.

AN UNUSUAL SPINE LESION, POSSIBLY TYPHOID

Report of a Case *

BY RICHARD E. KING, M.D., J. C. BLALOCK, M.D.,
AND WOOD W. LOVELL, M.D., ATLANTA, GEORGIA

From Georgia Baptist Hospital, Atlanta

Thirty years ago the problem of typhoid fever was of paramount importance to physicians. Today the condition has become uncommon and, within the next decade, it will perhaps come to be regarded as a rarity. This is especially true of one of its many protean manifestations, the "typhoid spine". Even when typhoid was a prevalent disease, typhoid spine was a rare entity, occurring in 0.2 to 0.3 per cent. of all cases of typhoid. A careful perusal of current orthopaedic reference works revealed that most authors refer to the typhoid spine briefly, as though it were a relic of the past. In view of this the authors are reporting the following case, as a reminder that the disease and its complications are still with us and must still enter into our differential diagnosis.

A Greek, sixty-three years old, who was a liquor salesman and a food handler in a restaurant, was admitted to Georgia Baptist Hospital on January 12, 1953. He had been relatively asymptomatic until two years before, when he had begun to notice a vague discomfort in the left flank and back. The onset was insidious and was not associated with trauma, lifting, or twisting. There was a vague history of occasional chills and fever, and there had been a weight loss of fifteen pounds in the past two years. At first the pain had begun in the area of the right hip, passing into the back, and shortly afterward radiating down into the left flank. The pain had been increasing in severity during the two months prior to admission, so that he had had to stop work. He had noted occasional radiation of the pain from the back along the anterolateral aspect of the left thigh to the knee. There was no history of lues or chancre. No other manifestations of joint involvement were found.

In September 1951 the patient had been seen in another hospital, where he apparently had a cystoscopy and "the kidneys were washed". Roentgenograms were made at that time and showed no evidence of a spine lesion. The "washing" of the kidneys gave him relief until several months later, when he again began to have back pain. There was no history of chest pain. He drank raw goat's milk about forty years ago, but he now drinks pasteurized milk. There was no history of contact with tuberculosis. The patient had only an occasional cough. He had a history of frequent constipation. There was no history of foot pain. The pain was worse at night and was associated with night sweats. The patient urinated three times daily and once during the night. He had never lived in the Southwest. He gave no history of lumbar punctures.

The patient localized the pain to the left flank, with some mid-line pain, and described it as being sharp and intermittent. He showed no evidence of pain in the leg or thigh. There was no paraesthesia, hypoaesthesia, or numbness in either lower extremity. The pain was not aggravated by coughing or sneezing. Bending was extremely painful, however, and the patient became very tired after excessive walking. Lifting also caused increase of the pain. The pain was aggravated in the evening and was also present at night. During the year before admission he had been absent from work a total of fifteen days because of back pain. Heat relieved the pain slightly; no other treatment afforded any relief.

Physical examination revealed a somewhat asthenic man who had considerable abdominal obesity. He walked with a rigid gait and did not limp or list, but his general posture was poor. There was no evidence of pelvic tilt, scoliosis, or kyphosis. In flexion, the patient bent at the hips only, keeping his back rigid. Extension was very limited. In lateral bending to the right and left the patient bent in the thoracic area, but the curve broke at the level of the twelfth thoracic vertebra. The remainder of the lumbar spine was held rigidly. He had bilateral paravertebral muscle spasm and we were unable to do a Trendelenburg test at that time. The pain was localized to the area of the third and fourth lumbar vertebrae. There was no tenderness at either sciatic notch or in the gluteal folds. The back was extremely flat and did not carry the normal lordotic curve. The lengths of the two lower extremities were equal. There was atrophy of the left thigh of 3.1 centimeters, as compared with the right, and atrophy of one centimeter of the left calf. Range of motion in the hips, knees, and ankles was within normal limits. The straight-leg-raising test was negative bilaterally at 100 degrees. The Patrick test was negative, as was the Braggard test, bilaterally. There was a positive Ely test bilaterally. The Achilles and plantar responses could not be elicited on either side, but the patellar responses

* Read at the Clinical Session of the Southern Medical Association, Atlanta, Georgia, October 28, 1953.

FIG. 1

FIG. 2

were equal and physiological bilaterally. The sensory examination showed slight hypo-aesthesia over the fourth and fifth lumbar distributions in the left foot. Examination of the prostate was essentially negative. Percussion of the heels caused pain in the back. The thyroid gland was normal. When the patient bent down to pick up objects, the back was held rigid and did not bend at all. There was no lymphadenopathy and no abdominal masses. The temperature was 101 degrees, the pulse was 84, and respirations were 20.

A chest roentgenogram was negative. Roentgenograms of the lumbosacral spine (Figs. 1 and 2) showed "extensive deformity of L-2 with a large defect in the anterior and inferior margin and dense sclerosis involving the anterior half. A shadow of bone density which projects over the upper margin of L-4 corresponds to the missing part of L-2. There is also irregularity of L-3. The disc spaces are preserved. Large bony bridges are seen crossing disc spaces L-2 and L-3, and L-3 and L-4 on the right. The normal lumbar curve is flattened but not obliterated. Conclusion—destruction of L-2 characteristic of malignancy and tuberculosis."

The barium enema and gastro-intestinal series were negative, as was urinalysis.

Red blood cells	3,850,000 per cubic millimeter
White blood cells	7,550 per cubic millimeter
Neutrophils	69 per cent.
Lymphocytes	31 per cent.

Sedimentation rate (Westergren method) was 112 millimeters per hour.

Serum calcium	4 milli-equivalents
Alkaline phosphatase	8 Bodansky units
Acid phosphatase	1.4 Bodansky units

Bence Jones protein was absent in the urine.

Mantoux skin test was negative in the first-strength test dose.

Serological tests were negative.

Agglutination test for Brucella was negative.

The agglutination tests for paratyphoid A, B, and Ox 19 were negative.

The agglutination test for typhoid H was positive in 1:20 dilution initially.

A second agglutination test was positive for typhoid H in 1:40 dilution and for typhoid O in 1:10 dilution.

FIG. 3

FIG. 4

(When asked at this time, the patient gave no history of ever having had typhoid or of having had immunization against typhoid.)

A urine culture was negative for typhoid bacilli. A stool culture showed growth of *Eberthella typhosa* which was serologically positive for *Bacillus typhosus*.

During the first and second weeks after admission the patient's temperature never went over 101 degrees; therafter he became afebrile and remained so throughout his hospital stay. The pulse on admission had been 84, but after that a relative bradycardia developed, the pulse ranging between 48 and 72.

A diagnosis of "typhoid spine" was made, and the patient was placed on absolute bed rest, with boards between the mattress and springs, on which he remained until February 12, 1953. He was then placed in a spica from the nipples to both knees until March 25, 1953, when he was fitted with an Arnold brace preparatory to a spine fusion.

On April 9, 1953, serial roentgenograms of the lumbosacral spine showed "no further destruction of involved vertebral bodies and definite calcification developing in soft tissues adjacent to them". On April 11, 1953, a McKenzie Forbes type of spine fusion was performed, which included the first to the third lumbar vertebrae, with grafts taken from the posterior aspect of the right ilium. No pus was encountered and the patient had an uneventful convalescence. He was placed on a course of 250 milligrams of chloromycetin every six hours, but nausea developed and the drug was discontinued. No other treatment was given. The stools became negative for typhoid organisms approximately six weeks after admission.

The patient was discharged from Georgia Baptist Hospital on June 29, 1953, wearing his brace. He had no further back pain and had gained twenty pounds in weight. The last roentgenograms (Figs. 3 and 4) showed progressive fusion between the first and third lumbar vertebrae and no further destruction of the vertebral bodies.

DISCUSSION

According to the case reports in the literature [1–6] there are a few clinical features of diagnostic significance in this condition. The pain is excruciating, every movement of the spine causing increased suffering. This pain is not relieved by the usual sedatives. Associated with the pain is severe spasm of the paravertebral muscle groups which serve to

splint the involved vertebral bodies. The back is held rigid in picking up objects from the floor. In all other activities the back is held straight, all bending occurring at the hips, and moves "all of a piece".

In addition, the roentgenographic appearance is usually believed to be diagnostic. In previous case reports the diagnosis was definitely made on the basis of roentgenograms alone. The destructive changes in the bodies are seen early; occasionally, there is thinning of the intervertebral discs between the bodies involved. Later, new-bone deposits are seen around the vertebrae which form clasplike projections connecting the bodies. Today, however, one might feel somewhat less positive in the diagnosis without further laboratory studies.

The most important aid in establishing the diagnosis is the Gruber-Widal reaction. Development of H (flagella) and O (somatic) antigens during the course of illness is strong evidence in support of typhoid. In some patients with typhoid, antibodies develop against the O antigen only. However, titers to O antigen disappear more quickly and do not reach the height of H titers as a result of the active immunization. It is reasonable to assume that the antibodies against O antigen are more significant in establishment of the diagnosis. Occasionally a patient may never have antibody titers over 1:40 or 1:80. It is also important to realize that in persons who have a previous history of typhoid or who have recently been inoculated (six to twelve months previously) with typhoid vaccine, antibodies may develop.

The treatment advised in previous case reports was bed rest; this resulted in improvement and consequent spontaneous fusion. The natural course of fusion can be hastened by surgical fusion; this was done in the case reported. Chloromycetin was not utilized fully in this case, but would probably be of benefit in hastening resolution of the disease process.

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HISTOPATHOLOGICAL ALTERATIONS OF ADRENAL AND ANTERIOR PITUITARY GLANDS IN PATIENTS TREATED WITH CORTISONE*

BY WARREN A. BENNETT, M.D., ROCHESTER, MINNESOTA

Section of Pathological Anatomy, Mayo Clinic and Mayo Foundation†

The therapeutic usefulness of cortisone and corticotropin in a large variety of conditions has led to their widespread clinical use. With the passage of time, it has become apparent that significant suppression of adrenal cortical function may result from administration of cortisone. When exogenous hormone has been withdrawn, recovery of normal adrenal function eventually ensues, but the time required probably varies greatly in different cases.

Fraser and his associates in a case report in 1952 first called attention to fatal acute postoperative adrenal insufficiency associated with atrophy of the adrenal cortex following the use of cortisone. Lewis and associates in 1953 reported a similar fatality in which the additional pathological finding of acute congestion and hemorrhagic infiltration of atrophic adrenals was noted at necropsy. Salassa and his associates in 1953 reported two additional cases of fatal postoperative adrenal insufficiency following the use of cortisone, in which atrophy of the adrenal cortices was demonstrated at necropsy.

The latter two patients [12] had been treated for prolonged periods with cortisone for rheumatoid arthritis. The anatomical evidence which supported the supposition that death was due to adrenal insufficiency consisted in atrophy of the adrenal cortices and histological changes in the basophils of the pituitary glands. The first patient had received cortisone in doses as high as 100 milligrams daily for approximately a year before admission. Melaena occurred while the patient was in the hospital. Roentgen examination revealed a penetrating gastric ulcer and a gastric resection was carried out. Administration of cortisone was continued until the day preceding operation. After operation the patient went into shock which failed to respond to emergency treatment, and death occurred thirty hours after operation.

The second patient had received cortisone as treatment for rheumatoid arthritis at intervals during a two-year period before admission. Steroid therapy had been discontinued for four and one-half months, except for six intra-articular injections of hydrocortisone, before bilateral bunionectomy was performed. Fifteen hours after the operation, shock which did not respond to emergency treatment developed. The patient died sixteen hours after operation.

In both of these cases the only significant pathological changes were found in the adrenal and pituitary glands.

PATHOLOGICAL CHANGES IN THE ADRENAL CORTEX ATTRIBUTABLE TO CORTISONE

In the past five years, the writer and his colleagues [14,15] have had the opportunity to study adrenal glands from 190 patients who had been treated with cortisone for various conditions, including acute leukaemia, periarteritis nodosa, disseminated lupus erythematosus, and rheumatoid arthritis. The duration of treatment, total dosage, and the time elapsed between cessation of therapy and death all varied greatly. It was noted that the adrenal cortices responded in essentially the same manner, irrespective of the condition treated. The outstanding features of the adrenal glands attributable to exogenous cortisone were low weight, narrowing and pallor of the cortex, and loss of lipid.

Objection has been raised to the use of weight as an indication of atrophy because

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1954.

† The Mayo Foundation is a part of the Graduate School of the University of Minnesota.

of wide variations in the weight of the glands in different diseases and in supposedly normal adrenals, such as those from persons dying suddenly as a result of acute myocardial infarction or accident. While variations in the weights of adrenal glands of normal persons and persons with various diseases may be great, we have found low adrenal weights more frequently among patients treated with cortisone than among patients taken at random.

To establish the latter point, the adrenal glands of forty-two patients who had received no cortisone were weighed after removal of all surface fat. The weights of these glands were compared with the weights of the adrenals of forty-six patients who had received varying amounts of cortisone. The patients in both groups had had similar diseases. The average adrenal weight in the group treated with cortisone was significantly less than the weight in the untreated group, but conspicuous atrophy was noted in only a few.

In all nine cases in which the patients had received cortisone for less than five days, the weights of the adrenal glands were within the same range as those of patients who had received no cortisone. When cortisone had been administered up to the time of death and for more than five days, the weights of the adrenal glands were significantly reduced. If the hormonal treatment had been discontinued for more than twenty days before death, the average weight closely approximated the average weight of normal adrenal glands. The data are too limited to permit further correlation with either dosage or duration of therapy; however, it is probable that the amount and duration of treatment play a part in the adrenal changes.

The adrenal glands in those cases in which cortisone had been given for more than five days and in a total dose of more than 450 milligrams showed definite evidences of atrophy. This atrophy (Fig. 1) was characterized by a decrease in weight of the gland as compared to the normal weight and a narrowing of the cortex with loss of yellow color. A section from a normal gland is shown in Figure 2.

A loss of lipid was found to be a rather constant feature of cortisone-induced atrophy, the inner part of the zona fasciculata losing its lipid first. The depletion of this substance (Fig. 3) persisted longer than did the decrease in weight. There was no apparent loss of cells; rather, the cells lost their lipid material and shrank in size. The nucleus remained quite normal, as did the cytoplasmic membrane. The interstitial tissues showed no apparent reaction. The lipid material stained with Sudan IV was seen to be diminished and in many instances was completely lacking from the cells. (Sudan IV is a non-specific stain and indicates only the lipid content.) By contrast, primary atrophy of the adrenal glands, which is the basis for some cases of Addison's disease, is characterized by degenerative changes and destruction of cells. The process is not reversible, whereas the atrophy induced by cortisone is alterative and reversible.

FIG. 1

Adrenal glands. Above, atrophy due to cortisone (850 milligrams in five days); below, normal gland.

After administration of the hormone had been stopped, the lipid material in the adrenal cortex gradually returned to normal. The lipid first appeared as small droplets which later seemed to fuse, so that finally several large droplets occupied the cytoplasm of the cells. In most cases this process began in the outer part of the zona fasciculata or zona glomerulosa (Fig. 4) in a patchy fashion and gradually extended throughout the zona fasciculata into the zona reticularis. When the outer part of

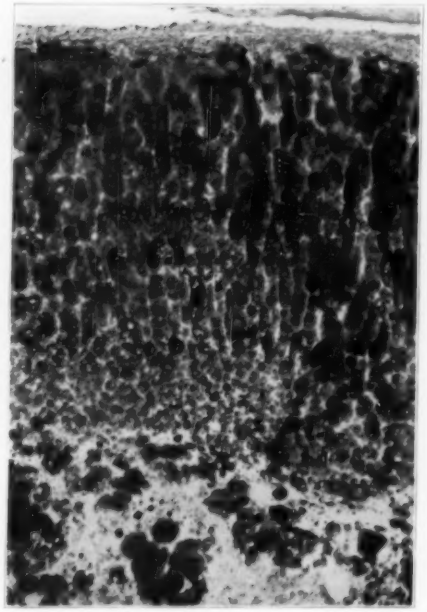

FIG. 2

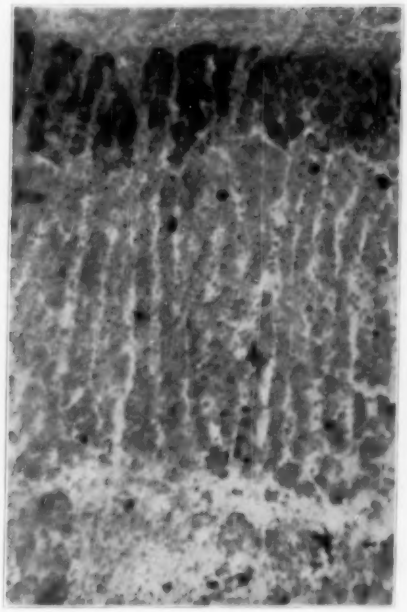

FIG. 3

Fig. 2: Normal pattern of the three zones of the adrenal cortex. Note the abundance of lipid material in the cortex. The glands weighed 13.8 grams (Sudan IV stain; × 55). (Reproduced with permission from: Postoperative Adrenal Cortical Insufficiency. Occurrence in Patients Previously Treated with Cortisone, by R. M. Salassa; W. A. Bennett; F. R. Keating, Jr.; and R. G. Sprague. *The Journal of the American Medical Association*, **152:** 1511, 1953.)

Fig. 3: Atrophy and loss of lipid of the adrenal cortex. A normal amount of lipid is present in the zona glomerulosa. The patient had received 850 milligrams of cortisone in seven days, but had received none during the two weeks prior to death. The glands weighed 4.5 grams (Sudan IV stain; × 100).

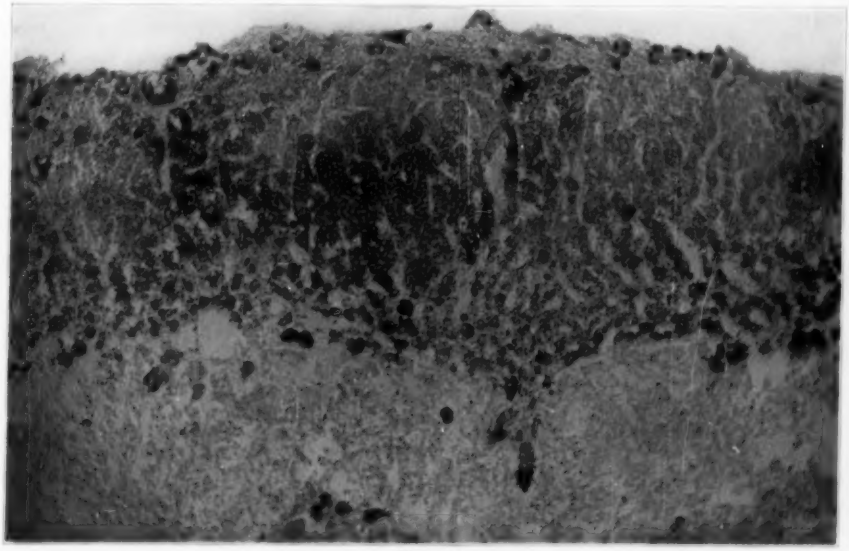

FIG. 4

Atrophy with loss of most of the lipid in a very narrow cortex. An unknown amount of cortisone had been given over a two-year period and up to the time of death. The glands weighed 5.6 grams (Sudan IV stain; × 70).

FIG. 5

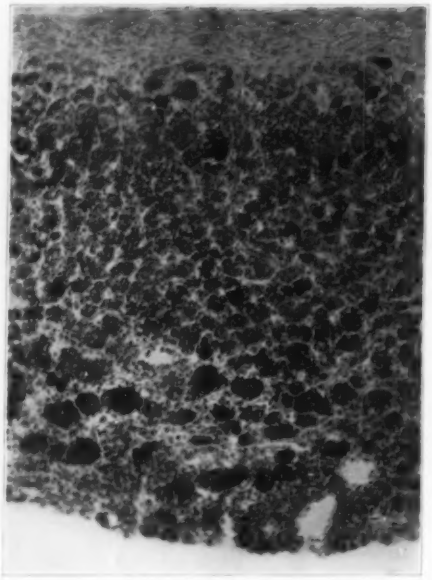

FIG. 6

Fig. 5: Loss of lipid in the adrenal cortex; dark-staining granules represent the only lipid remaining. A total of 1.3 grams of cortisone had been given in the fifteen days prior to death. The glands weighed 13.7 grams (Sudan IV stain; × 55). (Reproduced with permission from: Postoperative Adrenal Cortical Insufficiency, Occurrence in Patients Previously Treated with Cortisone, by R. M. Salassa; W. A. Bennett; F. R. Keating, Jr.; and R. G. Sprague. *The Journal of the American Medical Association*, **152:** 1512, 1953.)

Fig. 6: Atrophy of the adrenal cortex. There is decrease in lipid, but the gland is returning to normal. A total of 950 milligrams of cortisone had been given in ten days, but the patient had received none in the three weeks prior to death. The glands weighed 2.7 grams (Sudan IV stain; × 95).

the zona fasciculata was diffusely laden with lipid material, the zona glomerulosa became filled. In most cases, if the use of cortisone had been discontinued for more than six weeks, the adrenal glands were approximately normal in weight and there was an abundance of lipid throughout all zones (Fig. 5). In a few instances a paucity of lipid was noted for longer periods after withdrawal of cortisone (Fig. 6), in some instances as long as four and one-half months after withdrawal.

The changes described, constituting so-called atrophy of the adrenal gland, indicate a dysfunction of the cortical cells. This dysfunction may be associated with adrenal insufficiency and is a reversible process, but the exact time required for the cells to return to normal function cannot be determined accurately from histocytological studies. No apparent changes in the adrenal medulla resulted from the administration of cortisone.

PATHOLOGICAL CHANGES IN THE ANTERIOR LOBE OF THE PITUITARY GLAND ATTRIBUTABLE TO CORTISONE AND CORTICOTROPIN

Crooke described degranulization with hyalinization and vacuolization of basophils in cases of Cushing's disease. To these changes the term "basophilism" has been applied. Kepler was one of the first to call attention to the fact that the signs and symptoms of Cushing's disease in most cases are the result of adrenocortical hyperfunction and that basophilic (Crooke's) changes in the pituitary gland might be the consequence, rather than the cause, of adrenocortical hyperactivity.

Laqueur in 1950 observed Crooke's changes in pituitary basophils in patients treated with cortisone. Golden and Bondy found both Crooke's changes and an increase in the number of basophils in patients treated with corticotropin. Later, they reported experi-

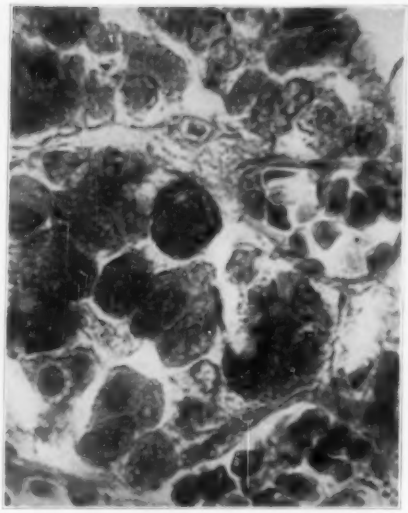

FIG. 7

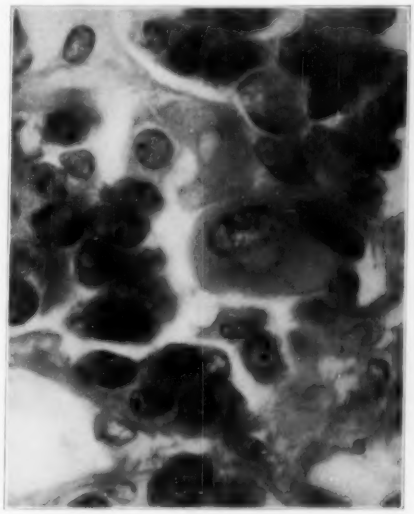

FIG. 8

Fig. 7: Normal pituitary gland showing granules in the basophils (Mallory-Heidenhain stain; × 830).

Fig. 8: Cushing's disease with hyalinization and vacuolization of basophils (Crooke's changes). Other cells are normal (Crooke's stain: × 800).

mental studies in rats with use of histochemical techniques, which indicated that the hyaline material in the basophils was not stored corticotropin.

Kilby and Bennett recently studied the pituitary glands of seventy-seven patients who had received cortisone, corticotropin, or both. In only one case was the pituitary decreased in weight. The glands were stained with hematoxylin-eosin, Mallory-Heidenhain, and Crooke's stains to differentiate chromophobes, eosinophils, and basophils (Fig. 7). The only cells which appeared to be affected by cortisone or corticotropin were the basophils, the rest of the gland remaining normal. This accounts for the virtual absence of change in weight of the gland, as the basophils represent only about 8 per cent. of cellular content of the normal pituitary.

The changes in the basophils (Fig. 8) resembled those described by Crooke in Cushing's disease and seemed to parallel the atrophy and diminished lipid content of the adrenal cortex of patients treated with cortisone. A similar but more intense response was found in the pituitary gland after corticotropin had been administered.

The initial phase of the changes in the pituitary glands of patients treated with cortisone or corticotropin appeared to be represented by a loss of the granules in the basophils (Fig. 9). This was often followed by clumping, resulting in reticulation of the cytoplasm (Fig. 10). Mellgren in 1945, in discussing hyperfunctioning adrenal cortices, described a similar reticulated cytoplasm in basophils associated with an increase in nucleolar-nuclear ratio.

With more prolonged administration of the hormone, the granules seemed to fade away, leaving the cytoplasm with a ground-glass appearance. During the phase of degranulization and reticulation, paranuclear vacuoles occasionally appeared (Figs. 11 and 12). The cytoplasm in some instances became hyalinized; this change was indistinguishable from that described by Crooke in Cushing's syndrome.

In the normal person, only an occasional basophil may show alterative changes of degranulization and hyalinization. In the patients treated with cortisone or corticotropin, on the other hand, all the basophils showed some phase of this alteration. The term "degeneration of basophils" should be avoided, for these changes appear to be alterative

FIG. 9

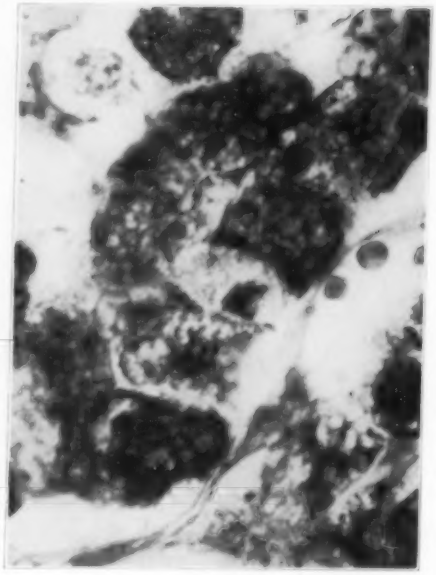

FIG. 10

Fig. 9: Pituitary gland. Degranulization of basophils (ground-glass appearance). A total of 1,350 milligrams of cortisone had been given during the five days before death. The diagnosis had been acute leukaemia (Mallory-Heidenhain stain; × 1000).

Fig. 10: Fusion of granules of basophils and reticulation of cytoplasm. A total of 34,500 milligrams of cortisone had been given over a period of 285 days, but none had been given during the last eleven days before death. The diagnosis was periarteritis nodosa (Mallory-Heidenhain stain; × 1000).

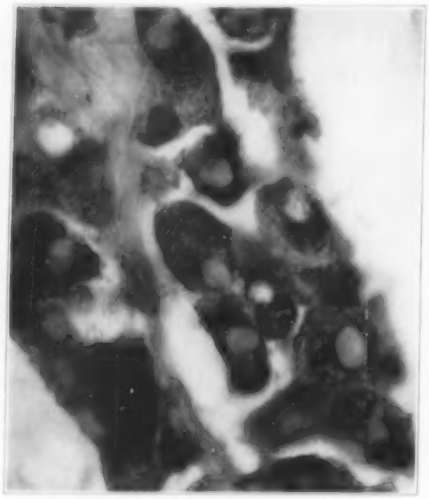

FIG. 11

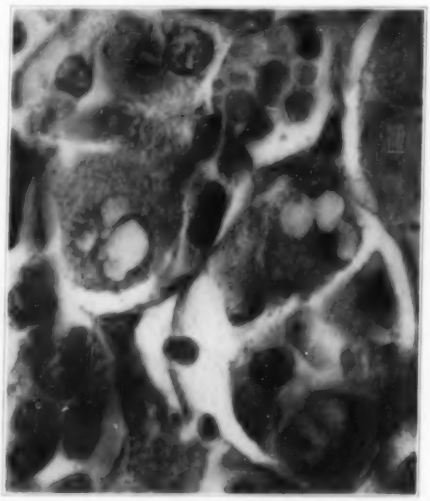

FIG. 12

Fig. 11: Loss of basophilic granules with vacuolization of basophils (perinuclear). A total of 1,745 milligrams of corticotropin had been given in a period of twenty days, but none had been given during the last three days before death. The diagnosis had been reticulum-cell sarcoma (Mallory-Heidenhain stain; × 1000).

Fig. 12: Vacuolization, loss of granules, and early hyalinization of basophils. A total of 1,700 milligrams of cortisone had been given in the last ten days before death. The diagnosis had been periarteritis nodosa (Mallory-Heidenhain stain; × 1000).

and reversible. The time of recovery of a normal type of granulation in the basophils cannot be accurately ascertained.

The total amount of cortisone or corticotropin administered, the duration of treatment, the time between cessation of treatment and death, and individual reaction to the hormone all may play a part in the changes in the pituitary and adrenal glands. A dose of 100 milligrams of cortisone a day for four days may result in degranulization of basophils. Hyalinization and vacuolization require from seven to fourteen days longer. The degranulization is probably associated with an alteration of the functional capacity of the basophils.

Pearse has described degranulization of mucoid cells (basophils) of the pituitary in rheumatoid arthritis and in Addison's disease. Also, the basophils were increased in size (amphophils of Mellgren). However, a review of the pituitary glands of five patients with rheumatoid arthritis who had received no steroid therapy revealed only an occasional hyalinized degranulated cell, probably representing normal alterative changes in the process of function of the basophils.

COMMENT

The morphological changes in the adrenal cortex which have been described are adequate to explain the postoperative adrenal insufficiency which has been observed in some patients who have been treated with cortisone. The significant observations can be summarized as follows:

1. Cortisone is capable of inducing atrophy of the adrenal cortex, but neither the factors of dosage and duration of administration, nor the time necessary for recovery, can be determined accurately, either clinically or morphologically.

2. The atrophy may be associated with impairment of adrenocortical function.

3. Both atrophy and depression of function of the adrenal cortex may persist for weeks or even months after withdrawal of cortisone.

4. In the presence of stress, the atrophy of the adrenal cortex may be associated with acute adrenal insufficiency.

Experience so far suggests that postoperative adrenal insufficiency of serious degree in patients who have been treated with cortisone occurs infrequently. Nevertheless, when it does occur, it may constitute a problem of serious significance.

Adequate pituitary function is essential for the maintenance of normal adrenal function. There is strong evidence that the atrophy, loss of lipid, and depression of function of the adrenal cortex which may be induced by cortisone are a consequence of suppression of endogenous production of corticotropin by the pituitary gland, rather than of a direct effect of cortisone on the adrenal cortex. Both cortisone and corticotropin are capable of causing similar histological changes in the pituitary glands of man and experimental animals. By the same token, both are presumably capable of suppressing the adrenotropic function of the pituitary. Therefore, in the present state of knowledge, it seems safest to assume that, for a period of time not yet determined after withdrawal of either cortisone or corticotropin, surgical stress may precipitate acute adrenal insufficiency.

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ANCHOR AND PROTECTOR FOR KIRSCHNER-WIRE SKELETAL TRACTION

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From the Beekman-Downtown Hospital, New York

Skeletal traction by means of a Kirschner wire is an important method of treatment for certain fractures. Although this method has been in use for many years, certain hazards and complications consequent to the use of the wire have always caused difficulties. The two most important of these are:

1. Inability to keep the sharp ends of the wires covered, in spite of the use of corks, adhesive tape and the like, with the result that patients, nurses, and doctors frequently sustain lacerations;

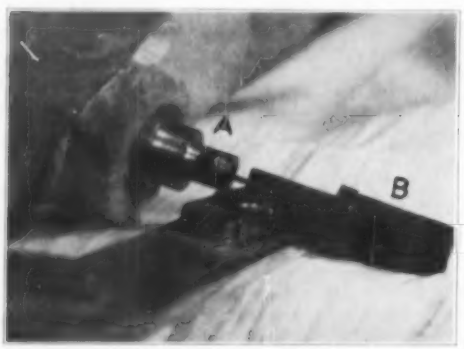

Fig. 1

Fig. 2

Fig. 1: Enlarged view of anchor (*A*) and protector (*B*) *in situ*.
Fig. 2: Skeletal traction through os calcis with Kirschner-wire anchor and protector in place.

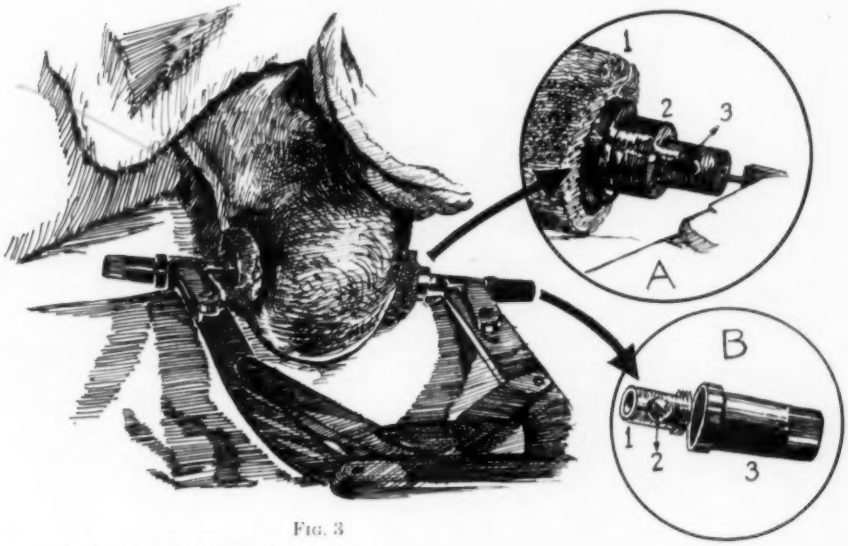

FIG. 3

Anchor and disassembled protectors:
A: Anchor
1. Foam-rubber cushion;
2. Body of anchor;
3. Set screw to fix anchor to wire.
B: Protector
1. Metal collar;
2. Set screw;
3. Plastic cap which screws onto metal collar.

2. Medial or lateral slipping of the wire after it has become loose as the result of bone absorption along the wire tract. This latter complication may cause infection of the soft tissues or even of the bone, and, if slipping is sufficient to bring the spreader into contact with the extremity, pressure necrosis of the skin and soft tissues may result.

At the Beekman-Downtown Hospital, New York City, for the last five years we have used two simple devices which have eliminated these complications.

After the insertion of the Kirschner wire and the application of sterile dressings to the wounds of entrance and exit, two anchors are applied over the wires as shown in Figures 1, 2, and 3. These anchors consist of metal sleeves faced with foam rubber and fitted with a set screw. They are slipped along the wire until the foam-rubber cushions are in contact with the dressings and then secured by tightening the set screws. The spreaders are then applied, and the wire is cut off to the desired length.

The protectors are then applied. Each consists of a metal collar with set screw and plastic cover. The collars are slipped over the projecting ends of the wire and secured by tightening the set screws. The plastic covers are then screwed onto these collars as shown in Figure 3, thereby covering the ends of the wire (Fig. 1).

Where the surface of the extremity is perpendicular to the wire, the anchors and foam-rubber cushions illustrated are used. However, when the wire is inserted through the tibia at the level of the tibial tubercle, for example, even pressure would not result on the skin with these cushions because of the obliquity of the tibial surfaces. To obviate this, cushions have been designed with the contact surfaces angulated to conform to the respective surfaces of the tibia. In this manner flat contact is obtained at the tibia, and the bodies of the anchors are maintained in a horizontal plane.

Since these two simple devices have been used, there have been no lacerations and no instances of skin necrosis or infection. Their use has become routine.

OSTEOID OSTEOMA OF THE SACRUM

Report of a Case

BY LIEUTENANT BRUCE M. CAMERON *, *Medical Corps, United States Navy Reserve,*
AND COMMANDER L. F. FRIEND, *Medical Corps, United States Navy*

From the Orthopaedic Department, United States Naval Hospital, Yokosuka, Japan

This case of osteoid osteoma of the sacrum is reported because of its unusual location and because of the problem it presented in the differential diagnosis of the patient's low-back pain. Although it has been stated that osteoid osteoma can occur in any bone, there has not been, to our knowledge, any report of its occurrence in the sacrum.

J. J. G., 989-33-04, male, aged twenty-one, was admitted May 10, 1953, to the United States Naval Hospital, Yokosuka, Japan, with the complaint of low-back pain. One year prior to admission, he had noted the insidious onset of intermittent dull pain, located in the distal third of the sacrum just to the right of the mid-line. The pain was localized, did not radiate, and was not related to exercise. It gradually increased in severity, and three months prior to admission was incapacitating and constant, with exacerbations at night causing insomnia. Six weeks prior to admission he had afternoon fever which varied between 99 and 100 degrees.

Fig. 1

Anteroposterior roentgenogram of the sacrum, demonstrating the lesion. There is an osteolytic area, surrounded by an area of sclerosis, and in the centrum is a nidus.

On physical examination, the only significant finding was marked point tenderness in the area lying to the immediate right of the fourth sacral spinous process. Examination of the lower lumbar spine was normal, as was digital examination of the anterior surface of the sacrum. All laboratory tests, including sedimentation rates, were normal.

The anteroposterior roentgenogram of the sacrum (Fig. 1) showed what appeared to be an "extra sacral foramen". It was an osteolytic area, about one-half the size of the normal sacral foramina, in the area of point tenderness. It was surrounded by an area of sclerosis, and in the center there was a small, sclerotic nidus. The lateral roentgenogram failed to demonstrate the lesion.

It was decided, because of the dorsal tenderness and negative lateral x-rays, that the lesion was lying on the dorsum of the sacrum. On May 21, 1953, the patient was operated upon (by L. F. F.) through a routine mid-line sacral approach. The tumor, a bluish nodule surrounded by sclerotic bone, was found in the area demonstrated by the roentgenograms. It projected more into the sacral canal than toward the dorsum. By means of a Stryker saw, a plug of bone, two centimeters in diameter, was removed, with the complete nidus in the center. Postoperative roentgenograms demonstrated that the lesion had been completely removed.

The microscopic sections showed the typical picture of osteoid osteoma (Figs. 2 and 3).

The patient's postoperative course was uneventful and in two weeks he was returned to full duty, symptom-free.

This case is presented because the rare location of the lesion had made the diagnosis difficult. The patient had been seen by many competent examiners prior to admission to

* On leave of absence from the McGehee-Cameron Clinic, Houston, Texas.

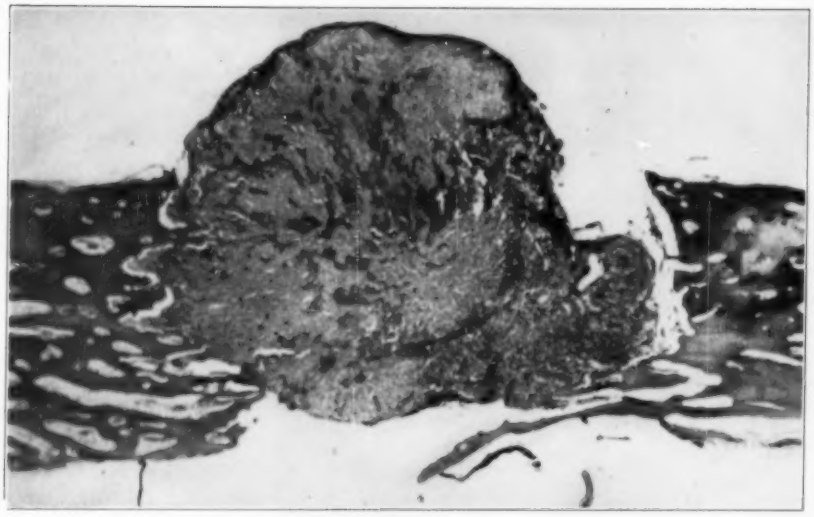

FIG. 2

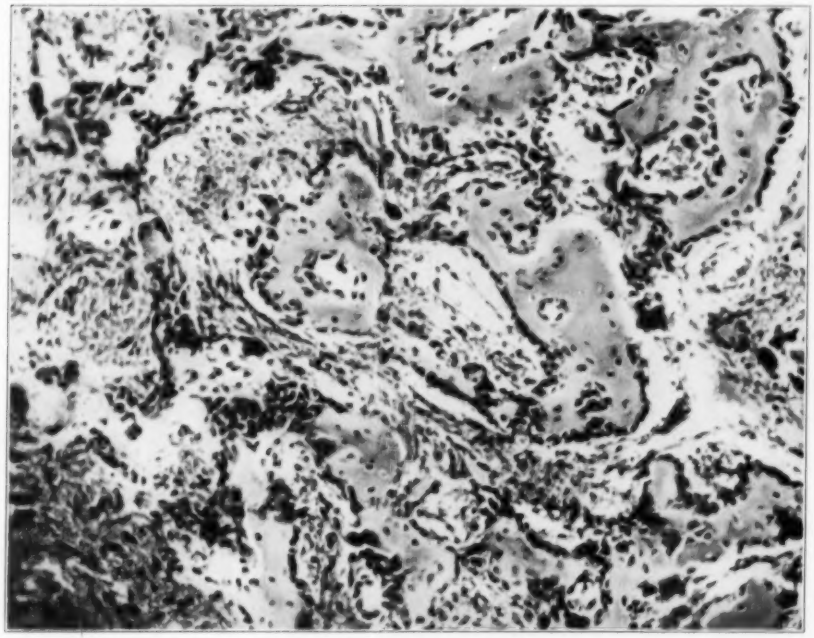

FIG. 3

Fig. 2 (× 11) and Fig. 3 (× 110): Photomicrographs of the specimen, showing the classical picture of osteoid osteoma.

the Hospital, and frequent roentgenographic examinations had been made in an effort to establish the diagnosis. The most indicative findings in this case were persistent low-back pain, localized tenderness, and the x-ray appearance of the lesion which was at first mistaken for an extra sacral foramen. The case demonstrates that an osteoid osteoma located in the sacrum may cause chronic low-back pain, and that after excision the patient may expect complete relief of his symptoms.

REDUCTION AND EXTERNAL FIXATION OF FRACTURE OF THE CLAVICLE IN RECUMBENCY

BY THOMAS W. COOK, M.D., ALLENTOWN, PENNSYLVANIA

For a number of years the writer has been reducing fractures of the clavicle and applying plaster fixation with the patient recumbent. There is nothing original about reduction in recumbence or about the particular type of immobilization described herein; the method described is, however, very simple, effective, and satisfactory.

A strip of aluminum, one-eighth of an inch thick, four inches wide, and thirty-eight inches long (Fig. 1) is placed across a gap of about eighteen inches between two tables, and upon these the patient lies supine with his head resting on one table, his body on the other table. The patient grasps a metal standard placed on either side, with each hand (Fig. 2). In this position reduction is effected by gravity; the operator is enabled to apply a figure-of-eight plaster cast about the shoulders with ease. Anaesthesia is not necessary.

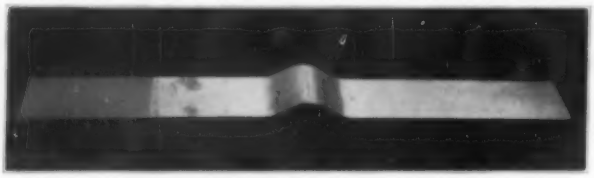

FIG. 1

FIG. 2

Before the patient lies on these separated tables, a piece of stockinette is applied about the shoulders, much in the fashion of a coat, the loose edges being fastened together in front over the sternum with a safety pin. With the stockinette in place, and with the patient recumbent on the two tables, the operator places four or five turns of cotton wadding about the shoulders in a figure-of-eight manner. Over each axilla is placed a thin strip of soft felt.

FIG. 3

A plaster-of-Paris slab is made of four-inch or six-inch reverses, about six inches less in length than the measurement across the patient's shoulders posteriorly. The plaster slab is covered with about eight layers of cotton

wadding, and is held by an assistant against the patient's shoulders posteriorly. If the slab is too long, its purpose is defeated; if it is too short the axillary loops are pulled together too tightly.

FIG. 4

Several figure-of-eight turns of plaster bandage are placed about the shoulders. As the plaster bandage is passed through each axilla, it is made ropelike and thin, and it is worked in close against the chest wall. To further decrease the bulk of the axillary loops, it is well to crush them with a pair of pliers before the plaster has taken its primary set. It is also desirable to pull the shoulders toward the floor with each turn of the plaster in an endeavor to overcome muscle spasm and to effect as complete a reduction as is possible.

The next step is to loosen the stockinette where it is pinned together over the sternum and to tie the axillary loops together with a gauze bandage across the front of the chest while the plaster is still soft. This bandage is left in place for about twenty-four hours; its purpose being to prevent lateral spreading of the axillary loops. The felt and stockinette are trimmed, and the stockinette is sewed over the axillary loops (Fig. 3). When the plaster has set sufficiently, the patient's head and trunk are raised, and the aluminum strip is withdrawn. The patient may then sit up. The stockinette is sewed over the posterior part of the cast. The finished product is shown in Figure 4.

AFTER-CARE

The patient should remain supine with a very low pillow for twenty-four hours, after which the gauze bandage holding the axillary loops is cut away, and the patient is allowed to be ambulatory. He is instructed to have someone take a piece of muslin about five inches wide and two feet long, moisten it with alcohol, and pass it back and forth under the axillary loops and the shoulder slab once or twice a day. The patient is told to keep the arms akimbo for a few days until he becomes accustomed to the dressing. If he is uncomfortable, he may lie down with a low pillow and let the shoulders fall back and relax. A sling is not worn. He is encouraged to use both hands for eating, dressing, holding his reading material, and for light work.

RESULTS

The writer has used this dressing fifty-one times. Children go to school the day after its application, using the hand on the injured side to write and to handle books. Housewives do light housework, cooking, dusting, and dishes. Office workers do their normal work, and patients drive their automobiles. The dressing is never changed.

DISLOCATION OF THE INTERPHALANGEAL JOINT OF THE BIG TOE WITH INTERPOSITION OF A SESAMOID BONE

BY PHILIP EIBEL, M.D., MONTREAL, QUEBEC, CANADA

From the Department of Orthopaedic Surgery, Jewish General Hospital, Montreal

Dislocations of the toes are comparatively rare. The majority of these injuries occur in the great toe at the metatarsophalangeal joint.[2] Of the even rarer interphalangeal dislocations, that of the great toe is again the most common.[3]

The author wishes to report a case of interphalangeal dislocation of the big toe with

FIG. 1

The roentgenogram revealed a dorsal dislocation at the interphalangeal joint of the big toe.

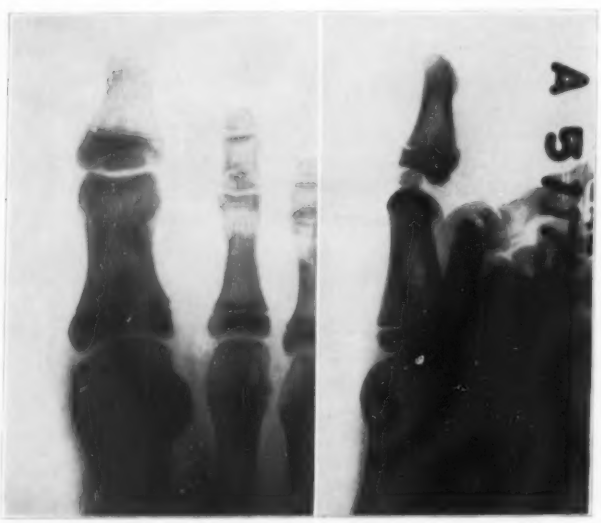

FIG. 2

FIG. 3-A

Fig. 2: Showing interposition of the interphalangeal sesamoid within the interphalangeal joint.

Fig. 3-A: Anteroposterior roentgenogram showing interphalangeal sesamoid of the contralateral big toe.

interposition or intra-articular inclusion of the interphalangeal sesamoid; this condition, to his knowledge, has been recorded only once before in the literature.[6]

CASE REPORT

G. S., a white male, aged fourteen years, stubbed his right big toe while playing football. He felt a sharp pain, but was able to finish his game. An hour later he found the pain insupportable and presented himself for examination at the Jewish General Hospital. An obvious dorsal dislocation of the interphalangeal joint of the big toe was present. The toe could not be moved actively, and only about 15 degrees passively. There was considerable swelling of the entire big toe. On the plantar surface a laceration was noted which extended medialward, virtually to the dorsum. Roentgenograms (Fig. 1) confirmed the clinical finding of dislocation and under demerol (seventy-five milligrams) reduction was successfully accomplished. It was noted, however, that considerable force was necessary to accomplish this and that the reduction was not stable. Roentgenograms made after reduction (Fig. 2) revealed the reason. There was an osseous body within the joint which interfered with reduction. This was taken to be an interphalangeal sesamoid, an opinion substantiated by identical findings in the roentgenograms of the contralateral big toe (Figs. 3-A and 3-B). Several attempts were made to dislodge this sesamoid from the joint by manipulation, but these were unsuccessful.

FIG. 3-B

Lateral roentgenogram of left foot.

The patient was then admitted to the Hospital and, under general anaesthesia, a transverse incision was made over the dorsum of the interphalangeal joint of the big toe. The extensor tendon was retracted to one side and the joint was opened. The sesamoid was seized with forceps, its plantar attachments were cut, and it was then removed. The joint was then closed with several interrupted catgut sutures and the skin was approximated with nylon. The dislocation was then easily reduced (Fig. 4) and was maintained in correct position by means of a tongue-depressor splint applied to the medial aspect of the big toe and the foot.

The postoperative course was uneventful. The sutures were removed on the ninth day after operation and the splint in three weeks after operation. Recovery was complete in five weeks.

FIG. 4

Roentgenograms made after removal of interphalangeal sesamoid.

COMMENT

The only previous report of such a case appeared in 1944. The author, G. M. Müller, described the lesion and an operative procedure for its treatment, but included no roentgenograms in his article. It is of some interest to note that he employed a lateral incision. The author would have preferred to use a medial incision. However, the case here described was complicated by a laceration and, in order to avoid a potentially infected area, we were compelled to use the slightly more difficult dorsal approach.

Müller pointed out that he found the sesamoid to be intracapsular and not intratendinous, in contradistinction to current anatomical descriptions[5,9]. Although the author did not expose the flexor hallucis longus, he feels that this tendon would of necessity have been damaged in the process of freeing the sesamoid from its soft-tissue attachments. The fact that this did not occur, as evidenced by the postoperative course, appears to corroborate Müller's observations. It may be noted in passing that Testut included this structure in the intracapsular group of sesamoid bones.

The frequency of development of the interphalangeal sesamoid is of some interest. Bizzaro, in 1921, showed this to occur in 5 per cent. of his subjects. This is at variance with the findings of Pfitzner, who found the frequency to be 50.6 per cent. Wood Jones explains the discrepancy as being due to the fact that Bizzaro's figures were based on x-ray examinations of relatively young subjects and Pfitzner's on postmortem examinations, the subjects of which were naturally in an older group. It seems certain that Bizzaro's figures are more in accordance with the experience of the average orthopaedic surgeon, who can recall seeing only one or two such cases in years of practice.

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EXPERIENCES WITH RESIN-CONTAINING PLASTER-OF-PARIS *

BY J. P. HARVEY, JR., M.D., AND THOMAS LASTRAPES, M.D., CLEVELAND, OHIO

From the Department of Orthopaedics, Western Reserve University, and the University Hospitals, Cleveland

A new type of material consisting of plaster-of-Paris and an aqueous solution of a melamine resin was used to prepare light casts which were waterproof and strong. In the course of the use of this material, an investigation was undertaken to determine the comparative strength of the cast, resistance of the material to water, and possible sensitivity in the patient to the resin.

METHODS

The new resin-plaster combination was used for seven months in both the cast rooms of the operating suite of the University Hospitals of Cleveland and in the Out-Patient Department. A breakdown of 118 casts applied to 100 patients is as follows:

Forearm casts	6	Long-arm casts	3
Short leg casts	31	Leg cylinder	4
Unilateral hip spica	4	Toe-to-groin casts	43
Bilateral hip spica	9	Arm splints	4
Shoulder spica	2	Body jackets	12 (including 1 Minerva jacket and 1 Risser jacket)

The material has been applied to patients of all ages, from the newborn to the very elderly. The new resin-plaster combination was applied over sheet wadding or over

* The materials used in this study were supplied by the Department of Research of Johnson & Johnson, New Brunswick, New Jersey.

stockinette. While the material was not put directly on the skin, it was used in the presence of incisional wounds, such as triple arthrodeses or fractures which had been subjected to open reduction.

The resin was originally supplied as a powder in a disposable container. The material was prepared by adding approximately two gallons of water and a small amount of the catalyst supplied to the powder and by stirring the mixture for approximately five minutes. Plaster-impregnated crinoline bandages were then soaked in this solution; these were applied in the usual fashion. The solution had to be used within two hours after mixing since it became hard. The resin solution could not be discarded by pouring it down the drain since it would harden and block plumbing. That was the reason for using the disposable container. However, the resin is now being supplied already mixed with plaster in the form of pretreated impregnated bandages, which need only to be dipped in water to which a catalyst has been added. The residual water containing the catalyst can safely be discarded down ordinary plumbing.

The resin-treated cast appears to be quite waterproof. While no patient deliberately went bathing, none of the walking casts which were used in rainy weather showed softening due to moisture. Nine casts were bilateral hip spicas which had been applied to babies with congenital dislocation of the hip; these showed no softening. The ordinary plaster casts which had previously been placed on eight of the nine children were soft and very soiled on re-examination. A fourteen-year-old girl who was treated in a resin-impregnated body cast had the cast washed daily with a damp cloth; the cast showed no softening or other ill effects.

Twelve casts (on the body and the extremities) were put on a dozen psychiatric patients who had various types of fractures. In spite of wetting, due to urinary incontinence, attempted removal, and other forms of mistreatment by the patients, these casts proved satisfactory.

Of the 100 patients treated, only one showed cutaneous sensitivity which might have been caused by the resin-containing plaster. This occurred in a four-year-old girl who had had wedge osteotomies performed for severe genu valgum, secondary to vitamin-D-resistant rickets. After one week, there was a three-centimeter area of reaction, much like that of a second-degree burn, which was noticed at the time the cast on the left limb was removed for inspection and for the removal of sutures. The child had experienced no itching or burning sensations and had not complained in any way. The area of reaction was dressed with zeroform gauze, and the standard plaster-of-Paris was used thereafter. The reaction rapidly subsided. There was no evidence of pressure nor was there any break in the overlying sheet wadding. The child showed no reaction where the skin came in contact with the edge of the cast. A patch test done later with the resin resulted in a slight erythematous reaction after forty-eight hours' application. This subsided twenty-four hours after removal and the original lesion has subsequently healed. There were no other instances of reaction to the resin.

The resin makes casts definitely harder and makes possible a strong durable cast even though considerably less plaster is used. In a few instances, some difficulty was encountered in the removal of these resin-impregnated casts, but when an electric cast-cutter was judiciously employed and the application of thick heavy casts was avoided, removal presented no problem. However, some of the clinicians who removed the casts by hand felt that definitely more effort was required. Although no extra time was required to remove these casts, sharp saws were needed. Because of the heat generated, one should avoid the prolonged use of a power-driven cutter over the same area.

SUMMARY

A resin has been developed which, when dissolved in water, provides a solution into which crinoline bandages with plaster-of-Paris can be dipped and then applied to make

a strong waterproof cast. More recently, the incorporation of the resin into the plaster-of-Paris bandage has obviated many of the objections (the time required to mix and prepare the plaster and disposal of unused material).

One hundred and eighteen casts were applied to all parts of the body in 100 patients of all ages for varying lengths of time up to four months. One skin reaction, similar to a small second-degree burn, was found which might be attributed to sensitivity to this resin.

The waterproofing and the strength of the casts are obvious advantages, particularly in instances in which prolonged application or contact with moisture exists. The cast material has also been of value when used on psychiatric patients.

A GONIOMETER FOR USE AT ANKLE FUSION *

BY JOHN J. GARTLAND, M.D., AND W. ROBERT SHERA, M.D., NEW YORK, N. Y.

From the New York Orthopaedic Hospital, Columbia-Presbyterian Medical Center, New York

It is extremely difficult at the operating table to judge with consistent accuracy the angle of plantar flexion required for ankle fusion. In many cases a faulty angle of plantar flexion necessitates a surgical revision of the arthrodesis. At the New York Orthopaedic Hospital from 1940 to 1949, the rate of operative revision of ankle fusions because of a faulty angle was 10 per cent. A surgical goniometer has been devised which enables the operator to set the ankle at any desired angle at operation and to hold it in that position until immobilization has been achieved.

Constructed by an instrument maker from our design, the device is made of stainless steel for strength and ease of sterilization, and it consists essentially of two flat tapered plates—the foot plate and the leg plate. The two plates are joined by a hinge which is secured by a removable pin. A removable protractor is attached for ease in setting the angle. A turnbuckle is used to obtain the desired angle and to lock the instrument in this position (Fig. 1).

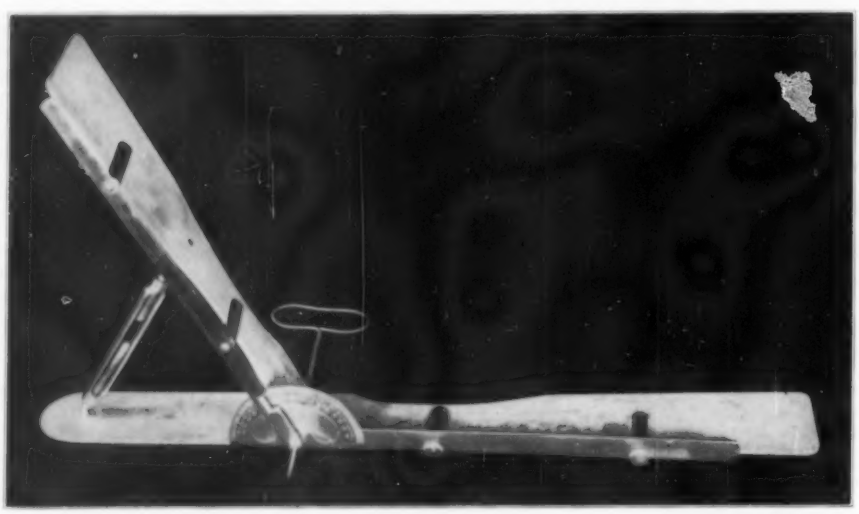

FIG. 1

* Based on an exhibit in the Gadgets and New Ideas Exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 1953.

When the instrument is to be used at operation, the extremity is prepared for fusion in the usual way and the foot and leg are covered with stockinette. Drapes below the knees are avoided. When the operator is ready to position the foot, he sets the goniometer at the desired angle, places the foot and leg in the proper position, and completes the arthrodesis. The leg piece must be securely held against the calf and the foot piece must be held against the heel and the metatarsal heads by an assistant. If internal fixation is to be used, the goniometer may be discarded after the insertion of nails or screws. If, however, no internal fixation is to be used, the foot must be left in the instrument until the completion of the operation. At that time dressings and sheet wadding are applied with care in the usual manner, and an anterior molded plaster splint is fitted to the leg. A circular gauze bandage, used to incorporate the wet plaster, the leg, and the instrument, is removed after the plaster has hardened. With the splint hardened, there is a stiff mold to which the ankle may be held in the same degree of equinus after the goniometer has been removed and while the circular plaster cast is being applied.

A theoretical source of error in the use of the goniometer may be caused by variation in the size of the calf muscle. It has been proved mathematically that this error will increase 1 degree for each one-quarter of an inch that the plane of the leg piece of the goniometer varies from a parallel relationship to the plane of the tibia [1]. This source of error is relatively negligible under anaesthesia when the calf muscle becomes soft and flaccid and is easily compressed.

RESULTS

In the two-year period from January 1951 to January 1953, the goniometer has been used by the Staff in twenty-seven ankle fusions. None of these required surgical revision. This compares favorably with the 10 per cent. rate of operative revision for the ankle fusions performed between 1940 and 1949.

Postoperative wedging, many times with anaesthesia, was necessary in 32 per cent. of the patients in the older series. In the series in which the goniometer was used (twenty-seven ankle fusions), postoperative wedging was performed once (4 per cent.).

A comparison of the discrepancy between the fusion angle estimated at operation and the final clinical angle was made for the two series. Accuracy within 5 degrees was attained in 93 per cent. of the fusions in which the goniometer was used, whereas similar accuracy was attained in only 68 per cent. of the older series.

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ARMIN KLEIN

1892–1954

On April 3, 1954, Armin Klein passed away. He had been given a warning some months previously by a heart attack that his life might be interrupted at any time, but he did not allow this to interfere with his regular daily life. When advised to slow down for the sake of his health, he replied, "I shall cooperate in every way, but I will not reduce my work". Thus, with a courageous heart and a cheerful spirit, he looked forward willingly to his day's work; and, on the day before his death, he was at his usual place in the Orthopaedic Clinic at the Massachusetts General Hospital and, by coincidence, sat for the photograph here reproduced.

While his close friends and his family knew that he might die at any time, his death was a shock because he appeared to be in good health. He arose from his bed on the morning of April 3 in a happy frame of mind and was actually joking, with a smile on his lips, at the moment death called him. Those who knew him well realized that he was the kind of person who would be ready to go whenever the call came, because his life was so full of sunshine, faith, and human understanding.

Armin's later academic days were spent at Harvard University and Harvard Medical School, where his superior mental attainments proved him to be a scholar of the highest grade and proficiency. After finishing Medical School, he decided to enter the field of orthopaedic surgery and took his training at the Boston City Hospital. Later, he became a member of the Orthopaedic Staff of the Massachusetts General Hospital and, when the new Beth Israel Hospital of Boston was opened, he was appointed Chief of its Orthopaedic Service. From these assignments, he advanced in the course of time to the position of Instructor at Harvard Medical School and Clinical Professor at Tufts College Medical School.

During his early career, he became associated with Dr. Robert Osgood in the study of scoliosis and later became Chairman of the United States Department of Labor's Committee for Investigation and Research on Scoliosis. Later on, his interest turned to the slipped capital femoral epiphysis, concerning which he wrote numerous articles and made a monumental contribution to our knowledge. Although his publications have been confined largely to these two subjects, they represent an enormous amount of work because of the thoroughness and accuracy of detail with which they were written.

He was a member of the following medical societies:

Boston Orthopaedic Club,
Massachusetts Medical Society,
American Medical Association,
The American Academy of Orthopaedic Surgeons,
The American Orthopaedic Association,
The American Board of Orthopaedic Surgery.

He also held membership in the Harvard Club.

As an individual, Armin Klein combined a number of extremely interesting and lovable qualities. He was a modest and retiring person who never put himself forward unless called upon to do so, but when he was forced into a position of prominence, his wit and cheerfulness invariably expressed themselves and were contagious. He was an exceptionally good story-teller; and, because of his natural gift for spreading cheer wherever he went, it was inevitable that he was frequently surrounded by a number of friends who were enjoying his company. His buoyant amiability was an unfailing source of pleasure to those who were associated with him.

To the younger men, his interns and residents, he was especially appealing, because he was easy to approach and displayed toward them a certain paternal interest which they not only appreciated but loved. He was never too busy to listen to their problems, their troubles, or their mistakes, and to sympathize with them, yet to give sound advice and to speak with the unswerving truth. Whenever his truthfulness was cruel or caused pain, he seemed able to temper it with kindness, humor, and reassurance.

For this reason, his House Staff never hesitated to come to him for help when they needed it, and they did so with gratitude and pleasure, knowing that they would receive wise counsel and the absolute truth as far as it was known. They had learned, as had all of his colleagues, that, although he was an independent thinker and a man of strong opinions and convictions, he had tolerance for the ideas of others and was, above all, intellectually honest. It could be said of him that he loved young people. He, therefore, made an excellent teacher, truly earning the affection of his students. Moreover, he was extremely loyal to them, as he was to his old friends, and this loyalty, one of his outstanding characteristics, won its reward by a deep feeling of nearness and appreciation for him.

One of his most admirable qualities was his ability to overlook the weaknesses in others, even when he himself was badly hurt and grieved by them, for the sake of enduring friendships or something else that he held to be more worth while. This is all the more creditable in view of the fact that by nature he was a very sensitive person. Such an attitude could only spring from an exceptionally fine character. This Armin Klein possessed and for this he was admired and loved.

His relationship with his wife and family was one of unusual devotion. In addition to his wife, he leaves two sons, Dr. Armin Klein, Jr., who is Professor of Psychology at the Hampton Institute, Hampton, Virginia, and Dr. Robert Klein, Professor of Pediatrics at the University of Pittsburgh Medical School, a daughter, Mrs. Brenda D. White of Newton, Massachusetts, a brother, Maurice Klein of Swampscott, Massachusetts, and five grandchildren.

In the Oregon lumber country they say you cannot tell the size of an evergreen tree until it is cut down. Now that Armin Klein is dead, we can measure his stature. It is lofty, inspiring, and among the most magnificent and the highest.

News Notes

The Annual Meeting of the **American Society for Surgery of the Hand** will be held at the Statler Hotel, Los Angeles, California, on Friday, January 28, 1955. The President of the Society for the current year is Dr. Joseph H. Boyes of Los Angeles.

The Twenty-second Annual Meeting of **The American Academy of Orthopaedic Surgeons,** under the presidency of Dr. T. Campbell Thompson of New York City, will be held at the Hotel Statler, Los Angeles, California, January 29 to February 3, 1955.

The 1955 Annual Meeting of **The American Orthopaedic Association** will be held at The Greenbrier, White Sulphur Springs, West Virginia, June 19 to 22.

The Eighth Annual Meeting of the **American Academy for Cerebral Palsy** will be held in Williamsburg, Virginia, at the Williamsburg Inn, on November 4, 5, and 6, 1954.

The Annual Convention of the **National Society for Crippled Children and Adults** will be held at the Hotel Statler, Boston, November 3 to 5, 1954.

Surgeons are cordially invited to attend the Sixth Congress of the **Pan-Pacific Surgical Association** to be held in Honolulu, October 7 and 8, 1954. Further information may be obtained from F. J. Pinkerton, M.D., Director-General, Pan-Pacific Surgical Association, Young Building, Honolulu, Hawaii.

The 1954 Annual Convention of the **Association of Military Surgeons** will be held at the Hotel Statler, Washington, D. C., from November 28 to December 1, 1954. The Executive Secretary is Stuart E. Womeldorph, Armed Forces Institute of Pathology, Washington 25, D. C.

The **Sociedad de Cirugia del Uruguay** announces the election of the following officers for the period 1954–1955:

President: Dr. Juan E. Cendán Alfonzo;
Vice-President: Dr. Enzo Mourigán;
Secretary-General: Dr. Oscar Bermúdez;
Treasurer: Dr. José Suárez Meléndez.

The **Alabama Orthopaedic Society** held its Third Annual Meeting on April 14, 1954, at the Mobile Infirmary, Mobile, Alabama. The following officers were elected:

President: Dr. David Vesley, Birmingham, Alabama;
Vice-President: Dr. Elias N. Kaiser, Montgomery, Alabama;
Secretary-Treasurer: Dr. John Fletcher Comer, Birmingham, Alabama.

The scientific program included case presentations illustrating various problems of hand surgery, epiphyseal stimulation at the knee, and epiphyseal retardation at the elbow, as well as a discussion of the treatment of slipped femoral epiphyses.

The **Sixth World Congress of the International Society for the Welfare of Cripples** will assemble at The Hague, Netherlands, September 13 to 17, 1954, under the presidency of Mr. J. M. Ravesloot. Through plenary sessions, demonstrations, panel discussions, and special meetings, the program will present analyses of developments throughout the world for the rehabilitation of the disabled and means for furthering such services in the medical, social, educational, and vocational fields.

Further information can be obtained from Norman Acton, Assistant Secretary General, International Society for the Welfare of Cripples, 127 East 52nd Street, New York 22, N. Y.

The National Foundation for Infantile Paralysis offers a limited number of fellowships to physicians interested in problems related to the management of poliomyelitis. The purpose of these fellowships is to train physicians in the various aspects of the total care of the poliomyelitic patient.

A limited number of fellowships to surgeons interested in orthopaedics are offered by The National Foundation for Infantile Paralysis. These provide for programs of training at centers which have been approved by the Council on Medical Education and Hospitals of the American Medical Association for residencies in orthopaedic surgery.

Information about the eligibility requirements and the methods of administration and application forms for these fellowships may be obtained from:

Division of Professional Education
The National Foundation for Infantile Paralysis
120 Broadway
New York 5, New York.

Book Reviews

ORTOPEDIJA. Prof. Dr. Bozidar Špišić. Zagreb (Yugoslavia), Skolske Knjiga, 1952.

Professor Špišić, a well known authority in orthopaedic surgery and a pioneer in that field in his own country, has published his textbook on orthopaedic surgery—the first to appear in the Serbo-Croatian language. The book is divided into nineteen chapters. The First Chapter deals with apparatus, technique, plaster-of-Paris braces, physical therapy and electrotherapy in general; while the Second Chapter is devoted to operative technique and deals with osteoclasis and osteosynthesis, joint resections, arthroplasty, nerve operations, and includes a review of operative complications. Then follow the Third and Fourth chapters which are devoted to deformities (congenital and static), contractures, and ankyloses. The Fifth Chapter deals more particularly with congenital deformities, and the Sixth with general bone diseases, such as chondrodystrophy, rickets, osteomalacia, and Moeller-Barlow disease. Beginning with Chapter 7, the text is built upon more specific pathological entities: syphilis and gonorrhoea (Chapters 7 and 8), tuberculosis (Chapter 9), arthritis deformans (Chapter 10), rheumatoid arthritis (Chapter 10), poliomyelitis (Chapter 13), the osteochondritides (Chapter 14), upper-extremity deformities (Chapter 15), deformities of the trunk (Chapter 17), and deformities of the lower extremities (Chapter 18). This last chapter is particularly voluminous, occupying 120 pages. As might be expected, some topics, such as bone and joint tuberculosis, congenital dislocation of the hip, and poliomyelitis, are given especially close attention.

Some critics may miss discussions of the newest surgical techniques, such as the use of the Judet prosthesis, but the book is stamped with the seal of cautious conservatism, as behooves a teacher of forty years' experience and one of the oldest pupils of Lorenz, Hoffa, and Lange, who may wonder if the use of the Judet prosthesis and other recent operative techniques are at the present stage of our knowledge subjects teachable to the undergraduate for whom this text is primarily designed. He states that he enters into the discussion of older methods of treatment only in so far as they have served in the progressive development of more recent and more effective procedures. From this point of view, a wholesome effect will have been attained if the student is made aware of what the names of Lorenz and Paci mean in the development of our present-day attitude toward congenital dislocation of the hip, or the name of Schulthess in scoliosis, or the names of Haglund, Menard, and Calvé in tuberculosis of bones and joints. That, with all his ties to an older era of orthopaedic surgery, the author has not lost sight of newer developments is shown by his paragraph devoted to the protrusion of the intervertebral disc, in which the work of Barr is given prominence.

A special chapter at the end of the book (Chapter 19) is devoted to amputations and artificial limbs, in which field the author, having participated in four wars, has amassed very considerable experience. This chapter includes discussions of all types of amputations, cineplastic procedures, and the more commonly used prostheses for the upper and lower extremities.

While the source material of the author is predominantly in German orthopaedics, he, being a pupil of eminent German authorities, has nonetheless read deeply in French, English, and American sources, so far as they have been available to him in his turbulent life. His many quotations and his authors' index testify to that.

For the native student who heretofore has had to depend on the foreign literature for his orthopaedic education, the appearance of this book must be a most welcome and highly appreciated event.

Arthur Steindler, M. D.

REGIONAL BLOCK. A Handbook for Use in the Clinical Practice of Medicine and Surgery. Daniel C. Moore, M.D. Springfield, Illinois, Charles C. Thomas, 1953. $11.00.

In spite of the fact that there are many good books on regional anaesthesia, there is a definite need for one such as Dr. Moore has written. For the student and the occasional practitioner of nerve blocks, it is most useful to have complete, independent, and precise descriptions of well recognized regional procedures, including indications, preparation of the patient, complications, and precautions. Such a handbook Dr. Moore has produced in a most readable fashion.

The author should be commended particularly for his chapters on the general subjects of the fundamentals of techniques, use of alcohol and depot anaesthetics, precautions with the use of spinal anaesthesia, and treatment of complications resulting from the use of spinal anaesthesia. His recommendations should do much to prevent the inexperienced from encountering complications and the experienced from overstepping the bounds of established therapy.

However, the reviewer must take exception to one recommendation: the routine use of intrathecal vasopressors with single-dose, and especially fractional-dose, spinal anaesthesia. This is certainly not an established procedure worthy of including in a basic test, and, for fractional-dose spinal anaesthesia, there is no recognized legitimate rationale. Also, the discouragement of regional procedures below the wrist or ankle must surely be the author's personal opinion.

In a text designed for students, it is to be regretted that the apothecary system of weights, the English system of measures, and colloquial names for drugs were used. Although proper terminology is set in parentheses, this double naming becomes annoying and, by Chapter 40, quite ludicrous. The recent university-encouraged use of the metric system throughout medicine has been a welcome step forward in promoting international understanding of medical literature. The author's concession to provincial medicine cannot have been farsighted. Also, adherence to standard nomenclature for the body planes and directions might have made some of the technical directions clearer.

Although the author excuses himself from including references, they would have added much to the authority of the text, especially the sections on pharmacology.

Even though Dr. Moore has allowed the expression of his personal views and choice of terminology to lower the standard of this book as a teaching text, it has a wide practical usefulness. It should add much to the effectiveness with which students, general practitioners, surgeons, and anaesthesiologists perform regional anaesthesia. It deserves a place at their desk-side.

Donald P. Todd, M.D.

Die gesunde und die kranke Wirbelsäule in Röntgenbild und Klinik. Pathologisch-anatomische Untersuchungen. 3. Aufl. Prof. Dr. G. Schmorl und Prof. Dr. H. Junghanns. Stuttgart, Georg Thieme Verlag, 1953. DM 72.

Junghanns states that he believes a Third Edition is now justified primarily because of the increased knowledge which has been amassed from studies of the vertebral column.

While the entire book has been revised and alterations of varying degrees have been made in all chapters, the author has made the most marked changes, as though by popular demand, in the chapters dealing with intervertebral-disc displacements and osteoporosis. New chapters have also been added, including a chapter containing statistical data on over 100 dissections in cases of spondylolisthesis and pseudospondylolisthesis. The rather brief, twelve-page discussion of congenital anomalies in the old edition has grown to forty pages, with particular attention being devoted to the rate of development of individual parts.

Another new chapter has been added on the vertebral column as a whole with attention focused on the function of the spine. Roentgenograms were made in the standing, weight-bearing, and various bending positions rather than in the old static positions made with the patient lying on a flat surface.

The chapter dealing with displacement of intervertebral-disc tissue in which particular attention is devoted to posterior disc protrusions, first described by von Luschka, has been enlarged. The author recognizes the contributions made by surgery and suggests that, although much may be learned by injecting the disc space with contrast media, he feels that the practice is too dangerous because of the likelihood of disc prolapse. He considers the question of possible pressure on the sympathetic fibers resulting from disc protrusions in the cervical region.

In dealing with osteoporosis, the author states that he believes that the spine is affected by osteoporosis more than any other part of the human skeleton. He accepts Dr. Fuller Albright's theories regarding the senile patient. For example, he agrees that some relief may be obtained by the judicious administration of sex hormones.

Perhaps the most valuable contribution contained in this new edition is the complete and up-to-date reference to original works. Thirty-four pages of bibliography, as compared with twelve in the First Edition, attests not only to the thoroughness of this author's study but demonstrates the interest in the subject by students and investigators universally. This alone makes the Third Edition an invaluable part of the reference library of every institution engaged in research study of the spine.

Robert J. Joplin, M.D.

Les Aspects Neurologiques des Malformations Congénitales de la Charnière Cranio-Rachidienne. Raymond Garcin et Doros Oeconomos. Paris, Masson et Cie., 1953. 2,015 francs.

Malformations in the region of the occipitospinal hinge have not been clearly described and are not clearly classified. The orthopaedic surgeon and, perhaps, even the roentgenologist are at a loss in the interpretation of the varieties of malformations found in this region. The authors consider that the term, "platybasia", introduced by the anthropologists, is used incorrectly. Platybasia may exist independently of basilar impression. The most recent investigations of Chamberlain, who described the palato-occipital line, and of Fishgold, who proposed the bimastoid line for the identification of basilar impression, together with the use of tomography, have permitted the establishment of certain criteria for definition of malformations in the region of the occipital bone and upper cervical vertebrae.

In the light of the most recent diagnostic advances, any abnormal position of the head or of the cervical spine which had its onset at an early age and is accompanied by neurological symptoms must be considered a congenital deformity of the occipitospinal hinge.

The appearance of neurological symptoms in these deformities at a more advanced age is characteristic and is not rare in other similar lesions, as exemplified by the symptom complex associated with cervical

ribs. There is no typical clinical picture. Every modality of neurological manifestations can be observed.

It is difficult, however, to explain all of the neurological findings by the existing osseous malformation. There is apparently a simultaneous development of malformations of the skeleton and of the nervous system. The disproportion of the advanced neurological manifestations and the minimal skeletal changes is sometimes striking and confirms the conclusion that both systems are unequally involved. The establishment of this important factor may eliminate uncertain and inadequate therapeutic undertakings. This clear and very useful text calls attention to the neurological manifestations associated with malformations of the occipitospinal hinge. The deformities of the atlas are comparable to those occurring in the lumbar region. However, the clinical manifestations in the cervical region are infinitely more complex and the surgical intervention in selected cases is more promising.

Although the book is apparently intended for the neurosurgeon, it is most instructive and useful for the orthopaedic surgeon.

A basic description of the abnormalities at the occipitocervical junction is followed by excellent descriptions of the neurological manifestations, differential diagnosis, and roentgenographic studies.

Seventeen cases in which there were neurological symptoms, associated with proved congenital osseous deformities, and two cases of secondary basilar impressions are reported.

The material is well organized. There is a very good index and an extensive up-to-date bibliography.

The orthopaedic surgeon who is able to read French will welcome this small informative and useful book. In some form or other it should be made available to the majority of other orthopaedic surgeons.

Emanuel B. Kaplan, M.D.

PERIPHERAL NERVE INJURIES. PRINCIPLES OF DIAGNOSIS. Ed. 2. Webb Haymaker, M.D., and Barnes Woodhall, M.D. Philadelphia, W. B. Saunders Company, 1953. $7.00.

The First Edition of *Peripheral Nerve Injuries* was published in 1945 as a diagnostic guide for medical officers. It effectively combined descriptions of the anatomy and function of peripheral nerves and the methods of clinical examination, with illustrative data sifted from the vast amount of material which had accumulated at the Armed Forces Institute of Pathology.

After three reprintings, an extensively revised Second Edition is now available. Although it is similar in format, it has been enlarged by the addition of a new chapter describing the different degrees of nerve injury in terms of the pathological changes. Other addenda of more practical interest to the orthopaedist deal with high-velocity missile wounds, "primary" and "secondary" nerve injuries, associated vascular and soft-tissue injuries, myostatic contractures, pain, trick movements, and electromyographic studies.

End results of nerve injuries occurring during World War II have permitted statistical analysis; also additional material has been drawn from the Korean conflict. A more scholarly approach is evidenced in this edition by the quadrupled bibliography in which considerable attention has been devoted to such details as the apparent enophthalmos in Horner's syndrome and the establishment of Hoffmann's priority in the description of Tinel's sign. Excellent photographs and drawings supplement the text.

The book is an admirable companion for anyone concerned with the fundamentals of diagnosis of peripheral-nerve injuries. The addition of a simple glossary might facilitate the comprehension of those who are but neighbors of neurology.

Thomas F. Broderick, M.D.

LIVING WITH A DISABILITY. AT HOME—AT WORK—AT PLAY. Howard A. Rusk, M.D., and Eugene J. Taylor. Philadelphia, The Blakiston Company, Inc., 1953. $3.50.

Rehabilitation of the war wounded was begun during World War I by Sir Robert Jones in England and by Biesalski in Germany. It is a far cry from those early days to the amazing organization of the Institute of Physical Medicine and Rehabilitation presided over by Dr. Howard A. Rusk, but the same spirit which animated Jones and Biesalski can be seen in this American expression of determination to help the handicapped.

In the volume entitled *Living with a Disability* Dr. Rusk and his associate, Eugene Taylor, have published 275 illustrations showing devices culled from every portion of the world which may be of service to the handicapped person in converting an abnormal life into a normal one. The volume is certain to be of the greatest help, both to the handicapped and to all those who have his welfare at heart,—physician, physical therapist, nurse, occupational therapist, and all those who live in intimate contact with the handicapped person.

This is essentially a practical book. It covers almost every detail of life from the simplest care of the body to the details of building a special home and of participating in complex handicrafts. The illustrations are derived from several hundred different sources, to each one of which due credit is given. The authors modestly withhold their own significant contributions. The mere fact of synthesizing this complex material and publishing it in a form which is simple and practical represents a notable contribution to the advance of the "fourth phase of medicine",—rehabilitation.

Leo Mayer, M.D.

RADIOLOGY OF BONES AND JOINTS. An Introduction to the Study of Tumours and Other Diseases of Bone. Ed. 5. James F. Brailsford, M.D., Ph.D., F.R.C.P., F.I.C.S. (Hon.). Baltimore, The Williams and Wilkins Company, 1953. $19.00.

This book is the result of forty-six years' experience and the revision of four previous editions. It is divided into two parts: The first is concerned with regional roentgenography, and the second is concerned with a general discussion of abnormalities and pathology of bones and joints. The book contains 828 pages of text and an extensive bibliography covering seventeen pages. The book covers all common and many rare diseases and syndromes affecting the skeletal system. The writing is clear and concise and is frequently flavored by the personal experience of the author. The book is well illustrated with numerous roentgenograms and pen-and-ink sketches. However, it is somewhat disconcerting to find that the illustrations are frequently not on the same page as the text which discusses them.

This book in previous editions has enjoyed a wide public and is considered by many to be a classic. The present edition maintains the same standards and deserves a place in every roentgenological and orthopaedic library.

Elliott B. Sweet, M.D.

SECOND ANNUAL REPORT ON STRESS. Hans Selye, M.D., Ph.D. (Prague). D.Sc. (McGill), F.R.S. (Canada), and Alexander Horava, M.D. (Lausanne). Montreal, Acta, Inc., 1952.

For this report, Prof. Selye has a co-author, the Librarian of the Institute of Medicine and Experimental Surgery at the University of Montreal. It is, perhaps, because of Dr. Horava's influence that the organization of the book is quite different from that of the previous report; it now resembles an extensive card catalogue of subjects, authors, and sources, arranged in a sequential manner. Practically the only narrative style maintained is found in the chapter on carbohydrate metabolism, and in Part I, in the section on the general physiology and pathology of stress, comprising fifteen pages. The instructions as to how to find one's way through the book are repeated in the 1952 report. A revised section devoted to the "principal objections against the stress concept" is also included as in the previous report. Prof. Selye is magnanimous in calling attention to the work of those who might be regarded as dissenters, and he devotes two pages to putting the record straight as to who has priority. There is a separate "Atlas" of half-tone illustrations on glossy paper, pertaining to experimental work; these reproductions of the original photographs from the various authors are excellent. Segregation of these from the text seems an improvement over the usual plan of including them in the text. Part III, "After-Thoughts", presents a formal "sketch for a unified theory of medicine" which, perhaps, many could read into the authors' earlier papers[1]. In summary, the Second Annual Report comprises an extensive library of references, the subject matter being anything of biological nature which influences the various endocrine glands. The world literature of the past year is covered, and many different languages are represented. It is a book strictly for reference rather than for reading.

1. Selye, H.: The Alarm Reaction. *In* The Cyclopedia of Medicine, Surgery and Specialties, **15**: 15–38, 1940.

Patricia H. Benedict, M.D.

THIRD ANNUAL REPORT ON STRESS. Hans Selye, M.D., Ph.D. (Prague), D.Sc. (McGill), F.R.S. (Canada), and Alexander Horava, M.D. (Lausanne). Montreal, Acta, Inc., 1953. $10.00.

The authors have again produced a monumental compilation of references. Their chief interest is, of course, experimental work relative to the general adaptation syndrome; to the biologist this book should prove a ready guide. In addition to the extensive bibliography, the book includes three special articles which merit attention. Clinicians will find the article on Hypertension, by D. M. Green, of special interest. The article by J. T. Wortham and J. W. Headstream on the Effects of Bilateral Total Adrenalectomy in Diabetics with Advanced Vascular Disease summarizes the authors' experience with this surgical approach to a metabolic problem. The third article on Neurophysiological Aspects of the Control of ACTH Secretion by Robert W. Porter refers to animal experiments, the counterpart of which have not yet been reported in the human patient.

Part One reviews the general physiology and pathology of stress so that the reader may be totally unfamiliar with the previous works of Selye and yet acquire familiarity with the basic concepts of the author. Part Two concerns the special physiology and pathology of stress; here he will find sections of references to research on a large variety of subjects: growth and bones, joints, acid-base balance, and hemopoietic system, to list just a few of the forty headings. As was the case with the *Second Annual Report on Stress*, this Third Report comprises a book to consult rather than one to read from cover to cover. The authors are to be congratulated upon their prodigious efforts in bringing up to date the references to work done the world over.

Patricia H. Benedict, M.D.

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Anales de Ortopedia y Traumatología (Montevideo), **6:** No. 2, 1953.
Annual Report (50th) of Toronto Hospital (for tuberculosis), Weston, Ontario, for the Year 1953.
Archiva Medica Belgica (Bruxelles), **8:** Index, 1953; **9:** Fasc. 1, 1954.
Asistencia Social (Merida, Yucatán), **3:** Núms. 12 y 13, 1953.
Boletin del Hospital Militar (Habana), **6:** No. 4, 1953.
Boletín del Instituto de Patología Médica (Madrid), **9:** Núms. 1, 2, 3, 1954.
Boletines de la Sociedad de Cirugía de Rosario (Rosario, Argentina), **20:** No. 5–6, 1953.
Boletines y Trabajos de la Sociedad Argentina de Ortopedia y Traumatología (Buenos Aires), **28:** No. 8, 1953; **29:** No. 1, 1954.
Bulletin on Current Literature (The monthly bibliography for workers with the handicapped). The National Society for Crippled Children and Adults, Inc., Chicago, **15:** Nos. 5, 6, 1954.
Bulletin of the National Society for Crippled Children and Adults, Inc. (Chicago), **16:** No. 12, 1954; **17:** No. 1, 1954.
Cirugía, Ginecología y Urología (Madrid), **6:** Núm. 6, 1953; **7:** Núms. 1, 2, 1954.
Cleveland Clinic Quarterly (Cleveland), **21:** No. 2, 1954.
Harper Hospital Bulletin (Detroit), **12:** Nos. 1, 2, 1954.
Médica (Matanzas, Cuba), **12:** Núm. 6, 1953.
The Medical Journal of Malaya (Singapore), **8:** No. 2, 1953; **8:** No. 3, 1954.
Medical Journal of Osaka University (Osaka), **4:** No. 4, 1954.
Medicina Práctica (Zaragoza), Núm. 90, 1953.
Proceedings of the Forty-seventh Annual Meeting of Life Insurance Association of America (New York), Dec. 8 and 9, 1953.
Protección Social (La Paz), Volumen especial, 1953.

Transactions of the American Orthopaedic Association

Volume I of *The Journal* (then called the *American Journal of Orthopedic Surgery*), published in 1903, took the place of Volume XVI of the Transactions of the American Orthopaedic Association. From time to time *The Journal* has requests for copies of the volumes issued prior to that date. Any reader having copies of these earlier volumes, which he is willing to dispose of, is requested to write to *The Journal*, indicating volumes available and selling price.

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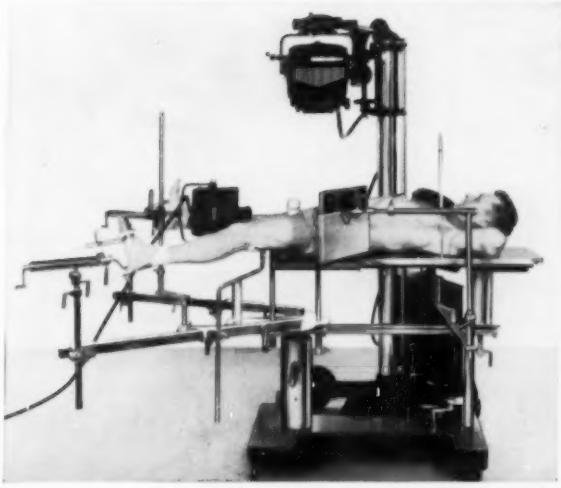

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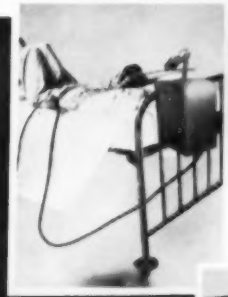

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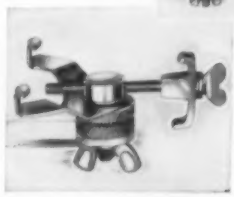

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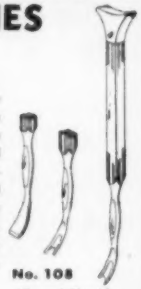

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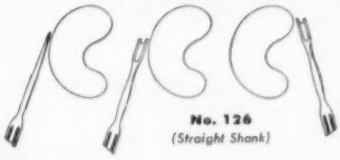

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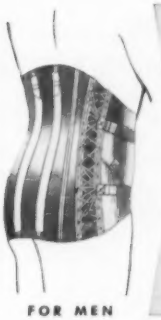

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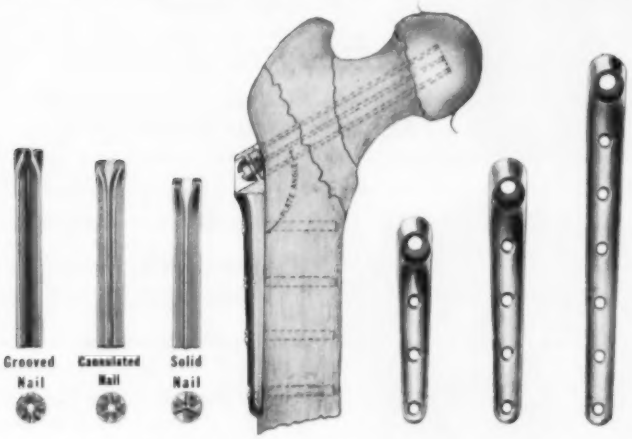

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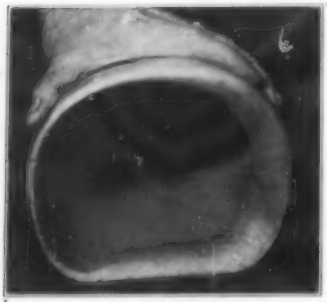

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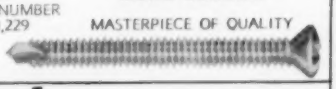

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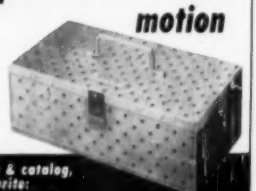

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